Low Contamination of Fish by Hydrocarbons from the Uniake G-72 (Shell Oil, Vinland) Wellsite Blowout in February 1984

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LOW CONTAMINATION OF FISH BY HYDROCARBONS FROM THE UNIACKE G-72 (SHELL OIL, VINLAND) WELLSITE BLOWOUT IN FEBRUARY 1984

by

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ABSTRACT

Zitko, V., L. E. Burridge, M. Woodside, and H. Akagi. 1984. Low contamination of fish by hydrocarbons from the Uniacke G-72 (Shell Oil, Vinland) wellsite blowout in Februsry 1984. Can. Tech. Rep. Fish. Aquat. Sci. 1305: iii + 43 p.

Cod (Gadus morhua) and haddock (Melanogrammus aeglefinus) fillet and liver were analyzed for hydrocarbons by spectrofluorometry and by gas chromatography-mass spectrometry. Fluorescence emission, di-, tri-, and tetramethylbenzenes, naphthalene and its methyl- and dimethyl homologues were used to detect contamination by gas condensate. Increased fluorescence and dimethylbenzenes were detected in the livers. It appears that fish were exposed to the gas condensate but the exposure was very low and did not affect the fish. The condensate was readily accumulated by juvenile Atlantic salmon in the laboratory. The excretion half-life was of the order of days. The potential of gas well blowouts to contaminate fish is higher than anticipated previously.

RÉSUMÉ

Zitko, V., L. E. Burridge, M. Woodside, and H. Akagi. 1984. Low contamination of fish by hydrocarbons from the Uniacke G-72 (Shell Oil, Vinland) wellsite blowout in February 1984. Can. Tech. Rep. Fish. Aquat. Sci. 1305: iii + 43 p.

Les hydrocarbures de filets et de foies de morue (Gadus morhua) et d'aiglefin (Melanogrammus aeglefinus) ont été dosés par spectrofluorométrie et par chromatographie en phase gazeuse-spectrométrie de masse. L'émission de fluorescence, les di, tri et tétraméthylbenzènes, ainsi que leurs homologues méthyl et diméthyl ont servi à détecter la contamination par les produits de condensation du gaz. On a détecté une augmentation de fluorescence et de diméthylbenzène dans les foies. Il semble que ces derniers ont été exposés aux produits de condensation, mais que l'exposition a été faible et n'a pas affecté les poissons. De jeunes saumons atlantiques en laboratoire ont rapidement accumulé ces produits. On mesure en jours la période d'excrétion. Le potentiel d'une éruption de puits à gaz comme contaminant des poissons est plus sérieux qu'on ne le croyait.

INTRODUCTION

At approximately 22:30 on February 22, 1984, a blowout occurred on the Vinland drill rig at the Uniacke G-72 wellsite, coordinates 44/11/29.0 N, 59/41/9.4 W, about 16 km north of the eastern tip of Sable Island. Gas and gas condensate were reported escaping from the wellhead and a sheen was observed extending from the rig for about 16 km in a southeasterly direction. The well was capped on March 3, 1984.

During the blowout, the gas condensate was escaping at an estimated rate of 300 barrels/day. Because of the expected relatively high volatility of the gas condensate, no wide-ranging contamination of fish was anticipated. However, to confirm this, samples of fish were analyzed by fluorescence and by mass spectrometry. In addition, gas condensate from a similar well has been analyzed, and the potential of this material to contaminate fish has been established in a laboratory experiment.

MATERIALS AND METHODS

A gas condensate from a nearby well (Mobile Texaco Venture B-13) was used as an analytical reference and in the laboratory uptake and excretion experiment.

Samples of fish were obtained from the blowout area and from a control site by Mr. Peter Hardie from the vessel CAPE BRIER on February 29 and March 1, 1984. The samples were received by DFO Inspection Personnel in Halifax on March 2, 1984, frozen immediately and, on March 4, 1984, delivered by car to the Biological Station in St.Andrews. The samples were stored at -20°C until dissection. Dissected tissues (Table 1) were stored frozen until analysis.

Hydrocarbons were extracted from the samples by steam distillation in an apparatus described by Veith and Kiwus (1977).

Ultraviolet and fluorescence spectra were obtained in spectrograde hexane on a Beckman Model 25 spectrophotometer and on a Perkin-Elmer MPF-2A spectrofluorometer, respectively. The spectra were recorded basically as described by Zitko (1975). Mass spectra were obtained on a Finnigan Model 4500 mass spectrometer connected to a Finnigan Model 9610 gas chromatograph equipped with a 30-m fused silica capillary column SE54-30N (J&W Scientific, Inc. No. 1FS4-23F), ID 0.25 mm, SE-54 film thickness 0.26 μm. Samples were injected by a J&W Model II "on-column" injector.

Gas chromatography was performed by on-column injection of 0.5 μL samples. The column was kept at 80°C for 3 min and then the temperature was raised to 250°C at a rate of 5°C/min. The range of m/z values from 50-300 was scanned every 2 sec. During some analyses the scanned range was extended to 500 or 650 m/z. Xylenes (dimethylbenzenes) molecular weight (m.w.) 106, trimethyl- and methylethyl-benzenes, m.w. 120, tetramethylbenzene and related hydrocarbons m.w. 134, naphthalene and its methyl and dimethyl derivatives, m.w. 128, 142, and 156, respectively were used to indicate the presence of the gas condensate. A standard containing xylenes, 1,2,3-trimethylbenzene, 1,2,3,4-tetramethylbenzene, naphthalene, 1- and 2-methyl-, 2,6- and 2,3-dimethyl-, and perdeutero-naphthalene was used for calibrations. For simplicity, the terms di-, tri-, and tetra-methyl- are used to designate classes of hydrocarbons according to molecular weight and not according to the chainlength of the alkyl substituents. Thus, for example, trimethyl- may mean trimethyl-, methylethyl-, or propyl-.

Table 1. Samples of fish.

Sample	Species	Station Lat. N	Station Long. W	Depth m	Weight kg	Length cm	Sex, Age	2,6DMN ppm[a] Muscle	2,6DMN ppm[a] Liver
173	Cod	[b]44°06'	61°10'4WH	73	2.17	60.5	M 6	0.34	0.18
175	"	[b] "	"		0.94	50.5	F 8	0.33	0.15
192	"	44 09	59 40 4WF	115	3.14	70.5	F 7	0.28	0.82
206	"	44 11	59 41 4WF	177	3.55	74.0	M 7	0.24	0.40
210	"	"	"		2.23	69.5	F 7	0.09	0.28
216	"	"	"		1.28	50.0	F 6	0.46	0.30
259	"	44 12	59 37 4WF	166	2.27	64.5	M 5	0.41	0.17
263	"	"	"		0.72	45.5	F 4	0.27	0.18
017	Haddock	[b]44 12	62 03 4WH	168	1.62	56.0	M 7	0.21	0.13
199	"	44 11	59 41 4WF	177	0.71	41.5	M 4	0.16	0.74
293	"	44 09	59 31 4WF	130	0.74	42.0	F 4	0.32	0.51

[a]Fluorescence emission intensity expressed as 2,6-dimethylnaphthalene; does not imply actual presence of this compound. Results are not corrected for extraction efficiency.

[b]Control area; all other samples Vinland site.

Water spiked with the condensate was steam-distilled for 1 h into 10 mL (initial volume) of spectrograde hexane. Hexane was collected quantitatively and diluted to have an absorbance (1 cm cell) of <0.1 at 290 nm. Fluorescence spectrum of the diluted solution was excited at 290 nm and was scanned from 300-400 nm. The response of the instrument was determined on solutions of 2,6-dimethyl naphthalene (emission at 339 nm).

Tissue (10 g) samples were homogenized in 200 mL tap water in a Sorval Homogenizer. The homogenate was transferred quantitatively into the steam-distillation apparatus. The remainder of the procedure was as described above for water.

For the uptake/excretion experiment, a homogenate of the gas condensate in water was prepared by mixing 37.5 mL of condensate in 2.4 L of water. Thorough mixing was accomplished using a Polytron homogenizer. The emulsion was delivered from a Mariotte bottle at 3.5 mL/min to a tank receiving water at 2.34 L/min. The tank was filled to 150 L and contained 27 juvenile Atlantic salmon (Salmo salar). Fish were 1 yr old and ranged in size from 20-71 g (mean=49.5) and 13-19 cm (mean=16.9). The tank was spiked with a condensate/water emulsion to a nominal concentration of 18.7 mg/L at the beginning of the test. Water samples were taken at 0, 4, and 8 h.

The addition of the homogenate was discontinued after 8 h, with only clean water being added to the tank at 2.34 L/min. Samples of fish (three per sample) were taken at 0, 4, and 8 h during the uptake phase, and at 4, 20, 40, 64, and 88 h during the excretion phase. Muscle and viscera (all internal organs) were dissected from each fish and individually frozen. Tissues of 2 fish from each sampling were pooled, extracted and analyzed.

A "range-finding" static acute toxicity test was performed with Atlantic salmon parr in Erlenmeyer flasks each containing 3 L of solution and 3 fish. Fish were <1 yr old and ranged in size from 3.6-9.2 g (mean=5.6) and 7.5-9.8 cm (mean=8.1). The solutions were gently aerated and the test was discontinued after 24 h. Nominal concentrations of the gas condensate were 200, 100, 40, 20, and 10 mg/L, respectively.

RESULTS AND DISCUSSION

CHARACTERIZATION OF THE GAS CONDENSATE

In terms of paraffins, the gas condensate contains hydrocarbons from about C9 to C26, with those from C10-C16 present in approximately equal concentrations, as judged by the intensity of the m/z=85 ions (Fig.1, scan 114 is C10; scan 581 is C16).

The ultraviolet spectrum of the gas condensate had maxima at 250-254 and at 210-220 nm with absorbance/(mg/mL) of 9.5 and 40.3, respectively. From these values, the gas condensate resembles furnace or diesel oil (Zitko and Carson 1970). The fluorescence emission maximum is at 323 nm. Fluorescence emission spectra of several benzenes and naphthalenes are similar to that of the gas condensate (Table 2); 2,6-dimethylnaphthalene was used as a reference standard.

Table 2. Fluorescence emission spectra (excitation 290 nm) of several methyl-benzenes and naphthalenes.

Compound	Fluorescence emission maximum, nm	Relative intensity
Xylene	318	0.49
1,2,3-Trimethylbenzene	316	0.30
1,2,3,4-Tetramethylbenzene	316	0.36
Naphthalene	324	0.58
1-Methylnaphthalene	324	1.00
2-Methylnaphthalene	322	1.01
2,3-Dimethylnaphthalene	320	1.18
2,6-Dimethylnaphthalene	327,339	1.45

The "indicator hydrocarbon" profile of the gas condensate shows the presence of xylenes, naphthalene and its methyl and dimethyl derivatives, and complex patterns for tri- and tetramethyl-benzenes (Fig. 2). Among the latter the main hydrocarbons appear to be methylpropylbenzenes (molecular ion at m/z 134 and base ion at m/z=105) in the partially resolved peaks starting in scan 150. The small peak in scan 250 originates from perdeuteronaphthalene. The profile of the standard mixture of hydrocarbons is shown for comparison (Fig. 3). Dibenzothiophene and its methyl- and dimethyl-homologues, suggested as indicators of oil pollution (Ogata and Fujisawa 1983), are present in relatively low concentrations (Fig. 4).

RECOVERY OF HYDROCARBONS FROM WATER AND TISSUES

The recovery of 2,6-dimethylnaphthalene from samples of water, spiked to a concentration of about 0.5 ug/mL, was 87.5%. The recovery from tissues spiked to approximately 2 μg/g was 77% for liver extracts and 35.2% for muscle extracts.

The presence of 2,6-dimethylnaphthalene was detectable qualitatively from the appearance of the fluorescence emission spectrum when the concentration of 2,6-dimethylnaphthalene was at least 1 μg/g in liver (Fig. 5). The detection limit for 2,6-dimethylnaphthalene in muscle is lower due to the low level of background UV absorbance (Fig. 6). The UV absorption of the distillates of muscle homogenates was low and the fluorescence spectra could be obtained directly on the distillates. On the other hand, the distillates of liver homogenates had considerable UV absorbance and had to be diluted before fluorescence measurements.

DETERMINATION OF AROMATIC HYDROCARBONS IN FISH

The fluorescence emission spectra of hydrocarbons isolated from samples of fish had a maximum at about 320 nm and lacked the second fluorescence emission maximum (or shoulder) of 2,6-dimethylnaphtalene at 339 nm (Fig. 5, 7). The maximum was also diminished in the distillates of the gas condensate, possibly indicating some changes in composition.

No evidence of the presence of 2,6-dimethyl-naphthalene could be obtained from the fluorescence emission spectra, but the fluorescence emission intensity was expressed quantitatively as 2,6-dimethylnaphthalene. This provides a reproducible quantitative scale similar to the "pyrene units"

suggested previously for mixtures of polynuclear aromatic hydrocarbons (Zitko 1975).

According to the indicator hydrocarbons profiles (Fig. 8-16; only profiles of samples with detectable responses are shown), most of the indicator hydrocarbons are not detectable. From Fig. 8-16 and Fig. 2 it can be seen that naphthalenes are absent. Trimethyl- and tetramethylbenzenes indicated in some samples do not match those of the gas condensate. Livers of cod samples 192, 206, 210, 259, and 263 contain dimethylbenzenes, as indicated by mass spectra in Fig. 17-21. However, there is no complete agreement between the profiles of these samples and the dimethylbenzenes profile of the gas condensate (Fig. 22-27). Cod sample 210 liver (Fig. 25) best matches the dimethylbenzene profile of the gas condensate.

The concentration of fluorescent compounds in distillates of muscle was practically the same for fish from the control and from the Vinland area, both in cod (control 0.34, Vinland 0.29 μg/g as 2,6-dimethylnaphthalene) and in haddock (0.21 and 0.24 μg/g, respectively). On the other hand, the concentration of fluorescent compounds in the liver of haddock was higher in the Vinland area (haddock 0.13 and 0.62 μg/g, for control and Vinland area, respectively).

The concentration of fluorescent compounds in cod livers also seems higher in fish from the Vinland area (control 0.17 and Vinland 0.36), but this difference is primarily due to a high fluorescence intensity of one sample (#192, Table 1).

The fluorescent compounds have not been identified as yet. The most intense peak in the gas chromatogram (scan 821, Fig. 28) appears to be a hexadecanoic acid (Fig. 29). Tetra- and pentadecanoic acid are in scans 691 and 754, respectively. Compounds in scans 807 and 922 may be some alkenoic acid esters (see Fig. 30 for the mass spectrum of 922). The compound in scan 731 is probably a phenyltridecane if m/z=260 (Fig. 31) is the molecular ion. This compound contains an alkylbenzene moiety, but is not related to the gas condensate and appears also in the liver distillate from the control area. The #192 liver sample contains several compounds with featureless mass spectra (one strong ion at m/z=100, Fig. 32). Such compounds are not present in the control sample (Fig. 33). Considerably more work is required to identify compounds responsible for the "elevated" fluorescence and to establish whether they are associated with the blowout, other oil exploration activities in the area, or general contamination of the coastal waters.

ACUTE TOXICITY OF THE GAS CONDENSATE

All Atlantic salmon parr died within 24 h in 200 μg/L (nominal) and 2 out of 3 died in 100 μg/L (nominal). There was no mortality at or below 40 μg/L. These values are of the same order of magnitude as reported previously by EPS (1983, unpublished report).

UPTAKE AND EXCRETION OF THE GAS CONDENSATE BY ATLANTIC SALMON

It is obvious from the composition of the gas condensate that it would be readily taken up by aquatic fauna. The prime purpose of this experiment was to provide the analytical laboratory with some "naturally spiked" samples as well as to give an estimate of the uptake and excretion kinetics (Table 3).

Table 3. Uptake and excretion of gas condensate by juvenile salmon. Concentrations are expressed as 2,6-dimethylnaphthalene.

Time, h	Concentration (μg/L) in water	Concentration (μg/g) in muscle	liver
0 Uptake	4.86	0.2	0.9
4	13.7	4.1	8.8
8	157[a]	6.2	11.1
4 Excretion		9.3	19.9
16		4.4	28.2
40		5.8	47.8
64		1.2	24.8
88		1.9	24.5

[a]Contaminated sample indicated by UV spectrum.

Exposure of the juvenile salmon to the gas condensate for 4 h is readily detectable by the indicator hydrocarbon profile both in the fillet and in the viscera (Fig. 34,35). Naphthalene and both methylnaphthalenes are present. Several of the dimethylnaphthalenes are also present and so are some of the major trimethylbenzenes. Interestingly, the tetramethylbenzenes are relatively accumulated much less. They are not detectable in the fillet and only one peak is present in the viscera. Several additional tetramethylbenzenes become detectable in the viscera after 8 h exposure (Fig. 36), but their profile bears little resemblance to that of the gas condensate (Fig. 2). On the other hand, there is a close agreement between the gas condensate and the hydrocarbons in salmon viscera in respect to trimethylbenzenes and dimethylnaphthalenes (Fig. 2, 36). The first dimethylbenzene peak is relatively enhanced in salmon viscera and the dimethylbenzene profile resembles fairly well some of the profiles obtained from cod livers (Fig. 37 and 22-27).

From the flow rate of clean water (2.34 L/min) and the tank volume (150 L), the clearance half-life from the tank was about 44 min [ln(2)/(2.34/150)]; practically complete removal of the gas condensate required about 7 h.

The excretion of the gas condensate from the fish tissues was fairly slow, with a half-life of the order of days (Table 3). The contamination is readily detectable from the hydrocarbon profile even after 88 h of excretion (Fig. 38, 39). Actually, the tetramethylbenzene profile of this sample resembles better that of the condensate than does the profile of the 8-h exposure sample.

In terms of fluorescence, the bioconcentration factor is about 1000 for fillet and 5000 for viscera. Additional experiments are required to perform quantitation in terms of individual hydrocarbons and to estimate the uptake and excretion rate constants.

CONCLUSIONS

It appears that cod and very likely haddock as well were exposed to very low levels of gas condensate as a result of the Vinland blowout. This conclusion is based on the detection of dimethylbenzenes in cod livers by mass spectrometry and on slightly elevated fluorescence of both cod and haddock liver distillates. By comparison with the exposure of juvenile Atlantic salmon in the laboratory, cod must have encountered only very low concentrations of the gas condensate. No other indicator hydrocarbons were detectable in cod in contrast to the hydrocarbons found in the Atlantic salmon. In addition, dimethylbenzenes were not detectable in the fillets.

Considering the low level of exposure, the likelihood of adverse effects on the fish is very low. On the other hand, the potential of the gas condensate to contaminate fish is higher than anticipated previously, if the sample of gas condensate available to us is representative. Depending on the circumstances, gas well blowouts could lead to a considerable contamination of fish. The contamination may last for a few months after the event.

Information on hydrocarbons, particularly aromatic ones, and on other lipophilic compounds in fish from Canadian Atlantic coastal waters, is very meager and a survey by gas chromatography-mass spectrometry and by fluorescence should be performed. Such a survey would document current levels of hydrocarbons and may detect unanticipated compounds. It may also indicate their distribution and sources. This information is essential for the assessment of the significance of the detection of unusual chemicals such as phenyltridecane and other as yet not fully identified compounds encountered in this study.

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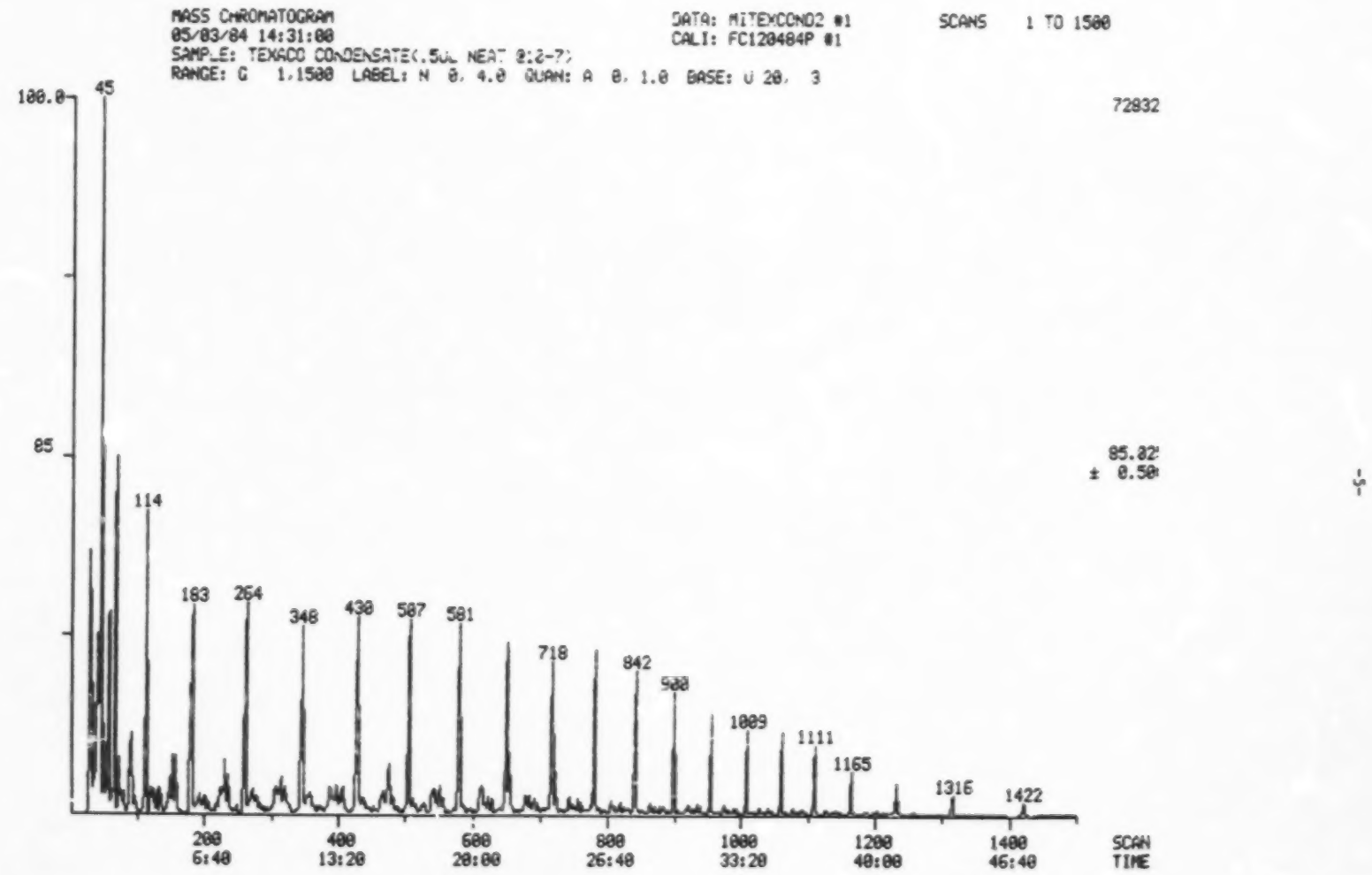

Fig.1. Reconstructed gas chromatogram m/z=85 of the gas condensate.
X-axis: scan numbers and times
Y-axis: intensity of m/z=85 (C_6H_{13}) ions, normalized to the most intense peak
Equally spaced major peaks (scans 114, 183,...) are a polymer-homologous series of paraffins starting with decane ($C_{10}H_{22}$ in scan 114).

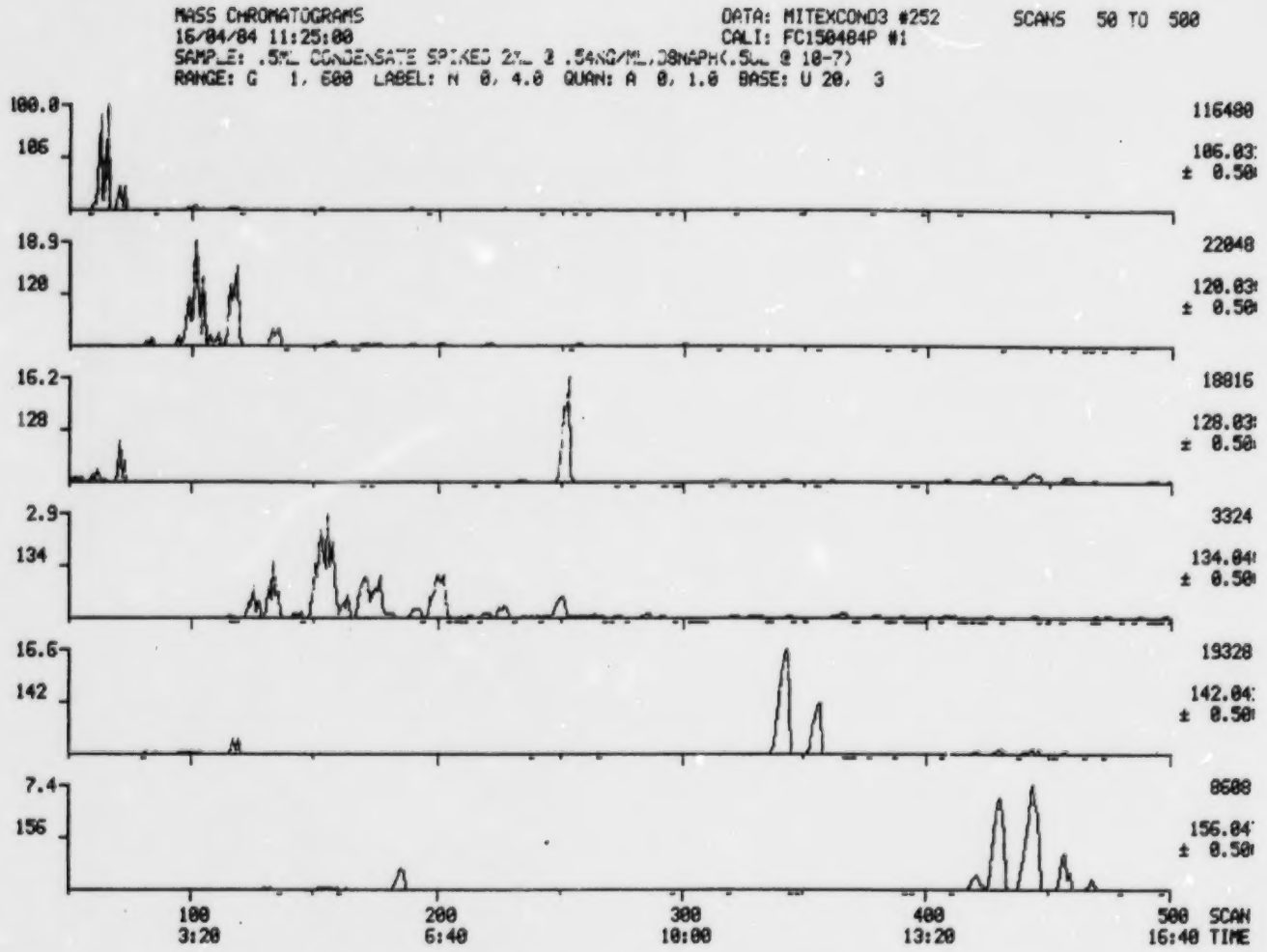

Fig. 2. Indicator hydrocarbon profile of the gas condensate.
X-axis: scan numbers and times
Y-axes: intensity of ions normalized to the most intense peak (see absolute intensities on the right);
m/z 106 dimethylbenzenes; m/z 120 trimethylbenzenes; m/z 128 naphthalene; m/z 134 tetramethylbenzenes;
m/z 142 1- and 2-methylnaphthalene; m/z 156 dimethylnaphthalenes
Note the complex profile of tri- and tetramethylbenzenes.

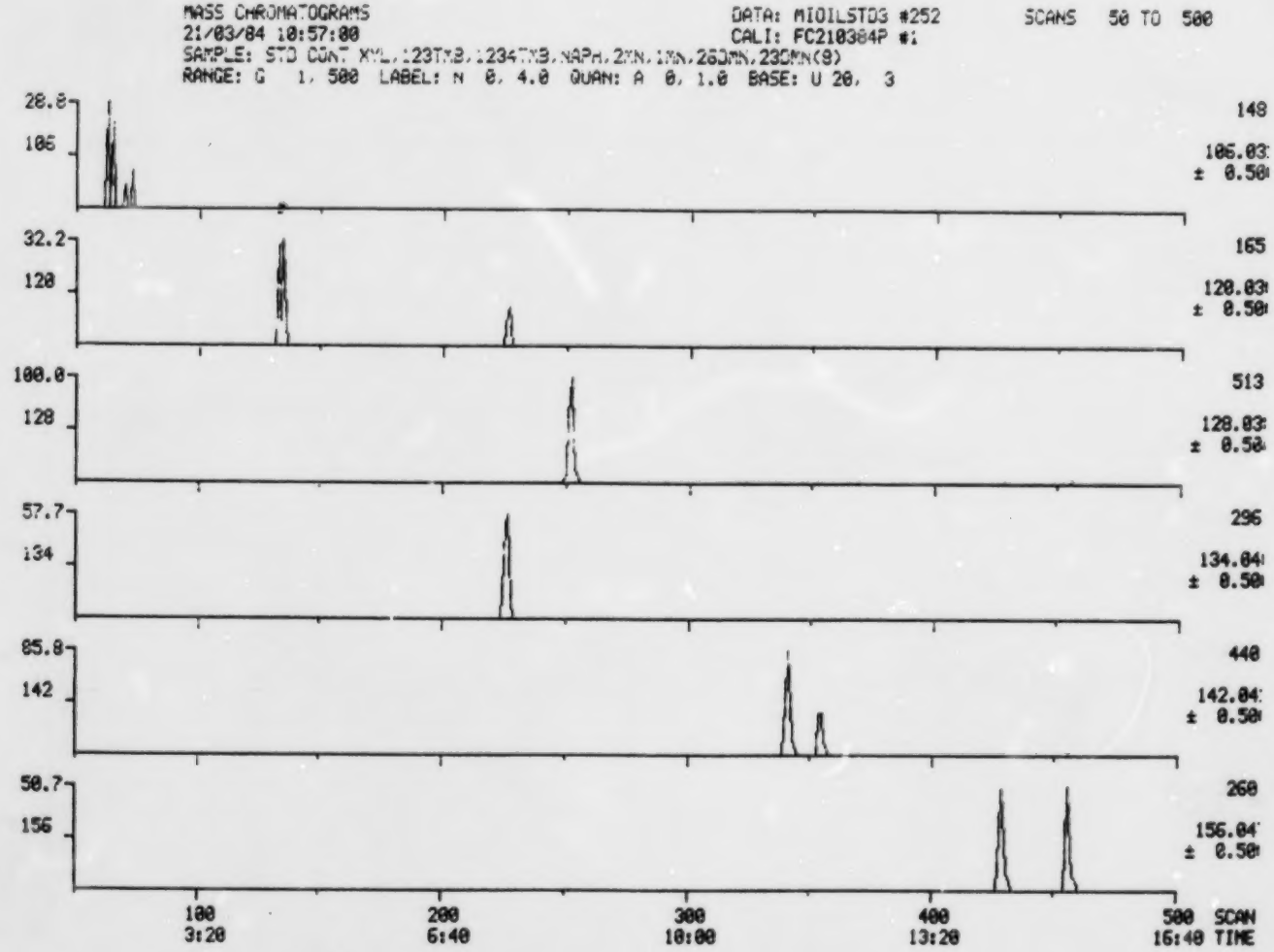

Fig. 3. Indicator hydrocarbon profile of prepared standard of hydrocarbons.
X-axis: scan numbers and times
Y-axes: Intensity of ions normalized to most intense peak (see absolute intensities on the right); m/z 106 technical xylene (o-,m-,p-xylene, and ethylbenzene); m/z 120 1,2,3-trimethylbenzene; m/z 128 naphthalene; m/z 134 1,2,3,4-tetramethylbenzene; m/z 142 2- and 1-methylnaphthalene (order of elution); m/z 156 2,6- and 2,3-dimethylnaphthalene (").

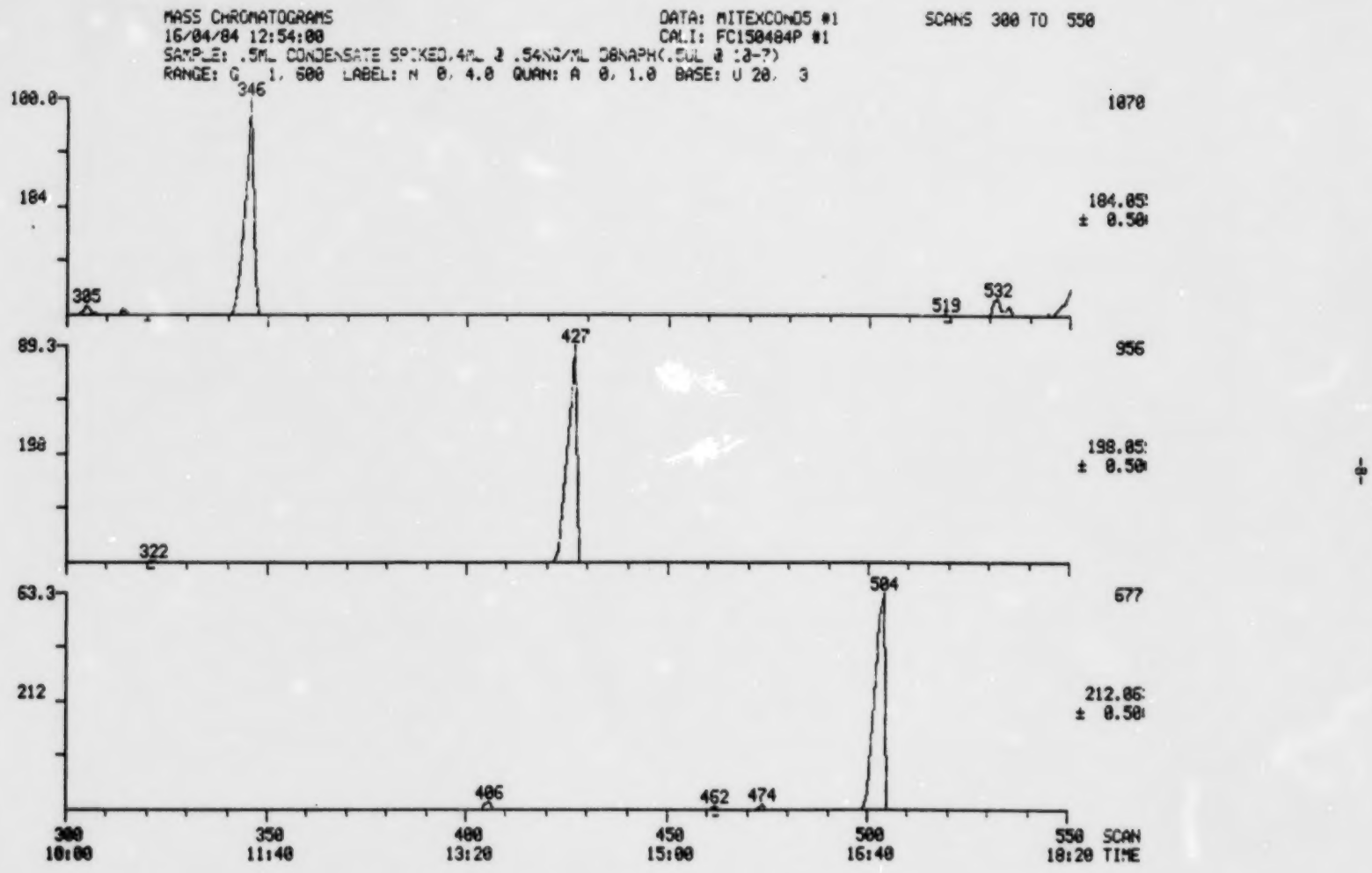

Fig. 4. Profile of dibenzothiophenes in the gas condensate.
X-axis: scan numbers and times
Y-axes: intensity of ions normalized to the most intense peak (see absolute intensities on the right); m/z 184 dibenzothiophene; m/z 198 methyldibenzothiophene; m/z 212 dimethyldibenzothiophene
Note the low absolute intensities (1070, 956, and 677).

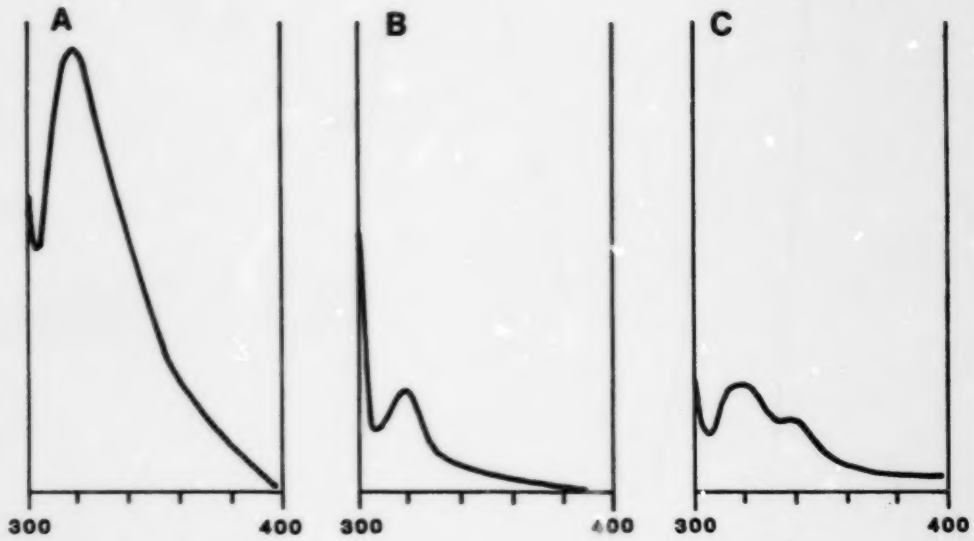

Fig. 5. Fluorescence emission spectra of steam distillates of cod (excitation wavelength 290 nm).

X-axes: emission wavelength, nm
Y-axes: fluorescence emission intensity, relative units
Cod sample #259: A-fillet, dilution 1/2; B-liver, dilution 1/30;
Control cod spiked with 2,6-dimethylnaphthalene: C-liver, dilution 1/30; 1 µg/g.

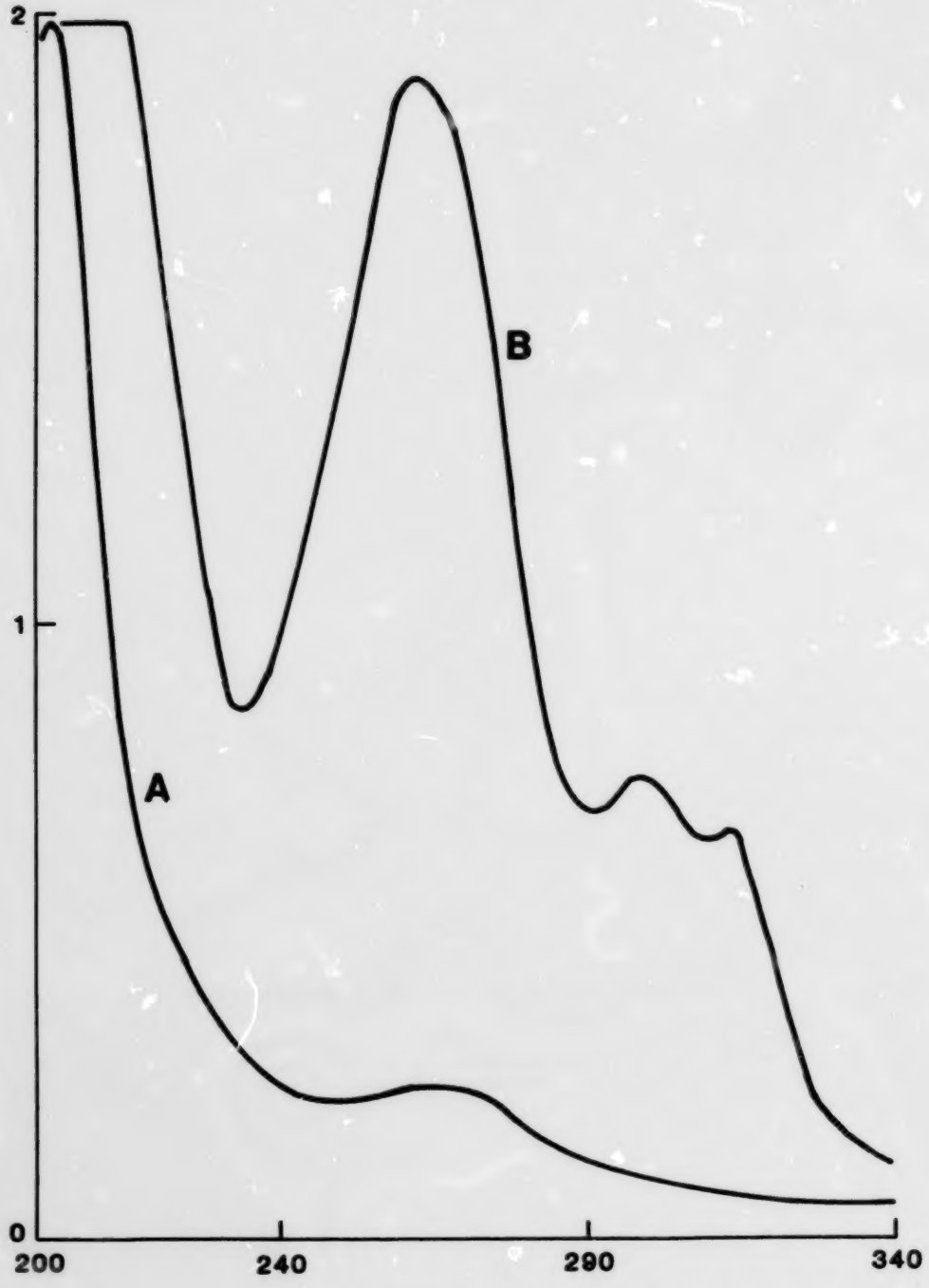

Fig. 6. Ultraviolet spectrum of steam distillate.
X-axis: wavelength, nm
Y-axis: absorbance in a 1-cm cell
Cod sample #259: A-fillet; B-liver.

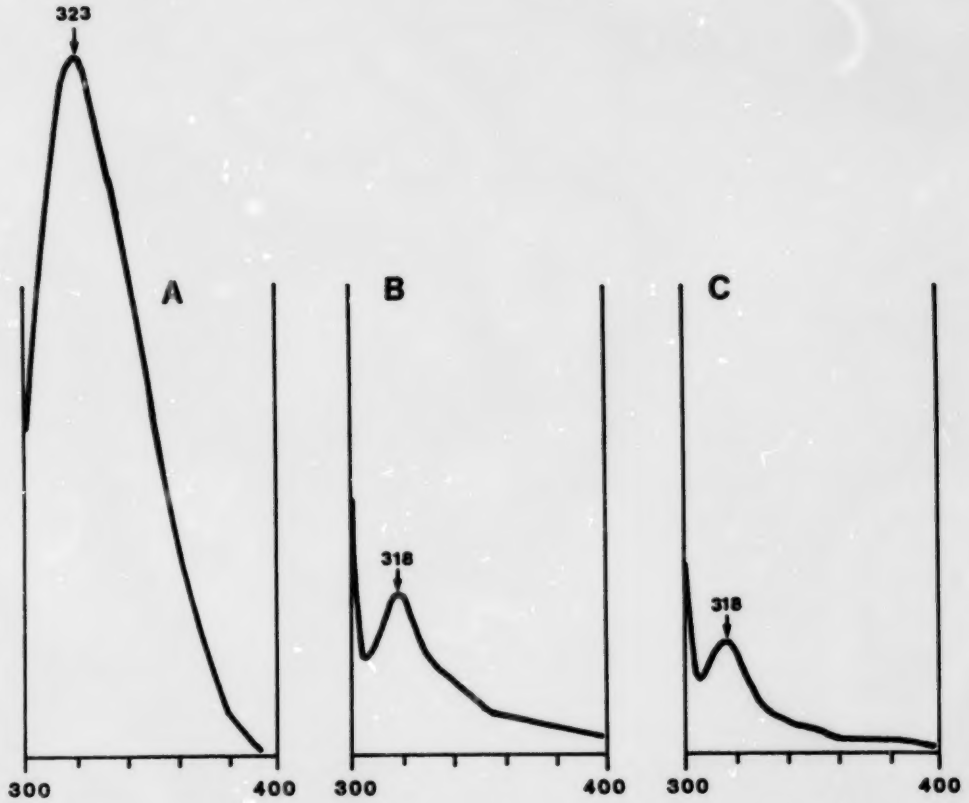

Fig. 7. Fluorescence emission spectra of steam distillates of cod (excitation wavelength 290 nm).

X-axes: emission wavelength, nm
Y-axes: fluorescence emission intensity, relative units
Gas condensate: A-dilution 1/200,000;
Cod sample #173: B-fillet, dilution 1/10; C-liver, dilution 1/30.

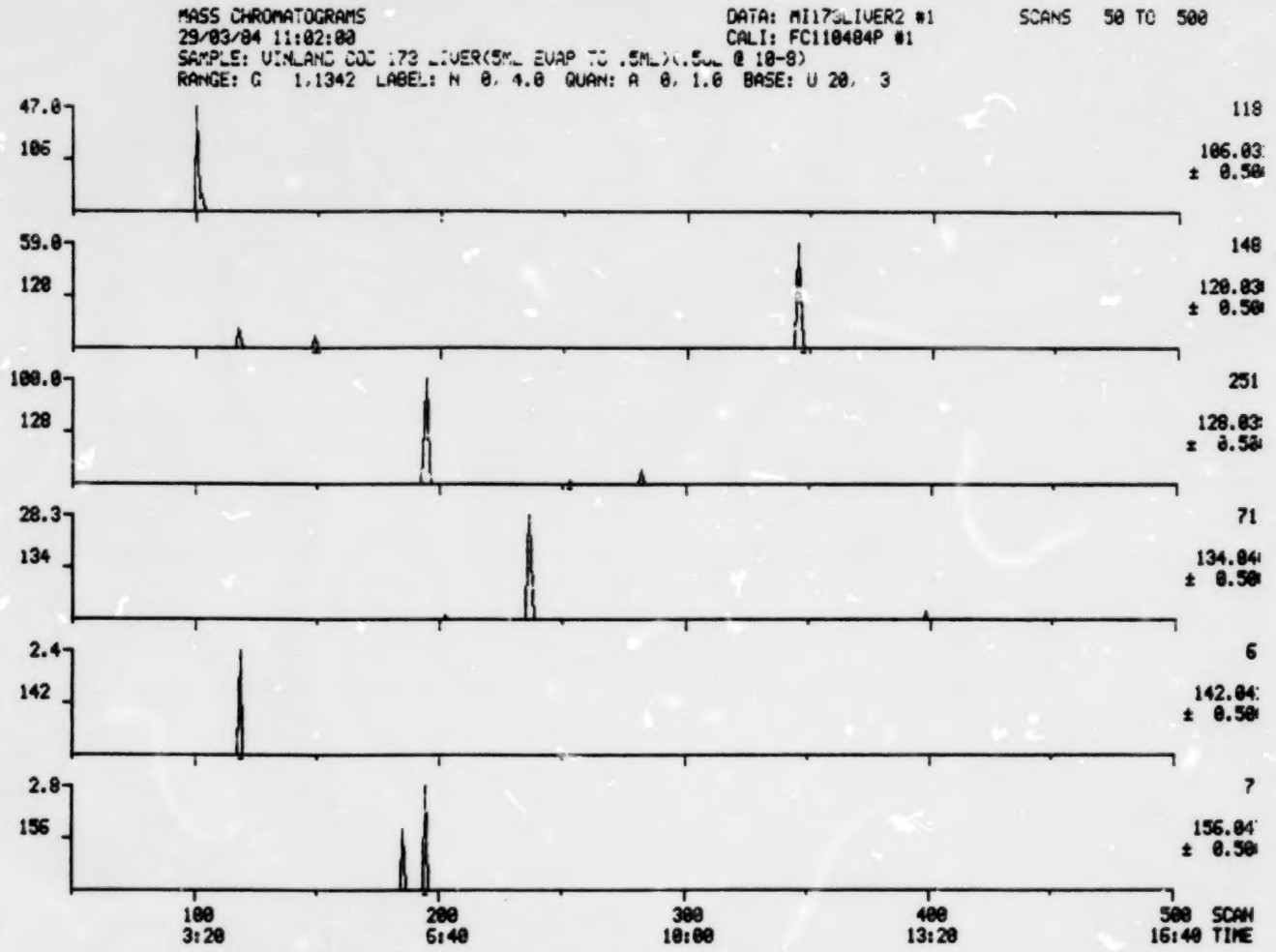

Fig. 8. Indicator hydrocarbon profile, cod #173 liver.
X-axis: scan numbers and times
Y-axes: intensity of ions normalized to the most intense peak (see absolute intensities on the right); m/z 106 dimethylbenzenes; m/z 120 trimethylbenzenes; m/z 128 naphthalene; m/z 134 tetramethylbenzenes; m/z 142 1- and 2-methylnaphthalene; m/z 156 dimethylnaphthalenes.

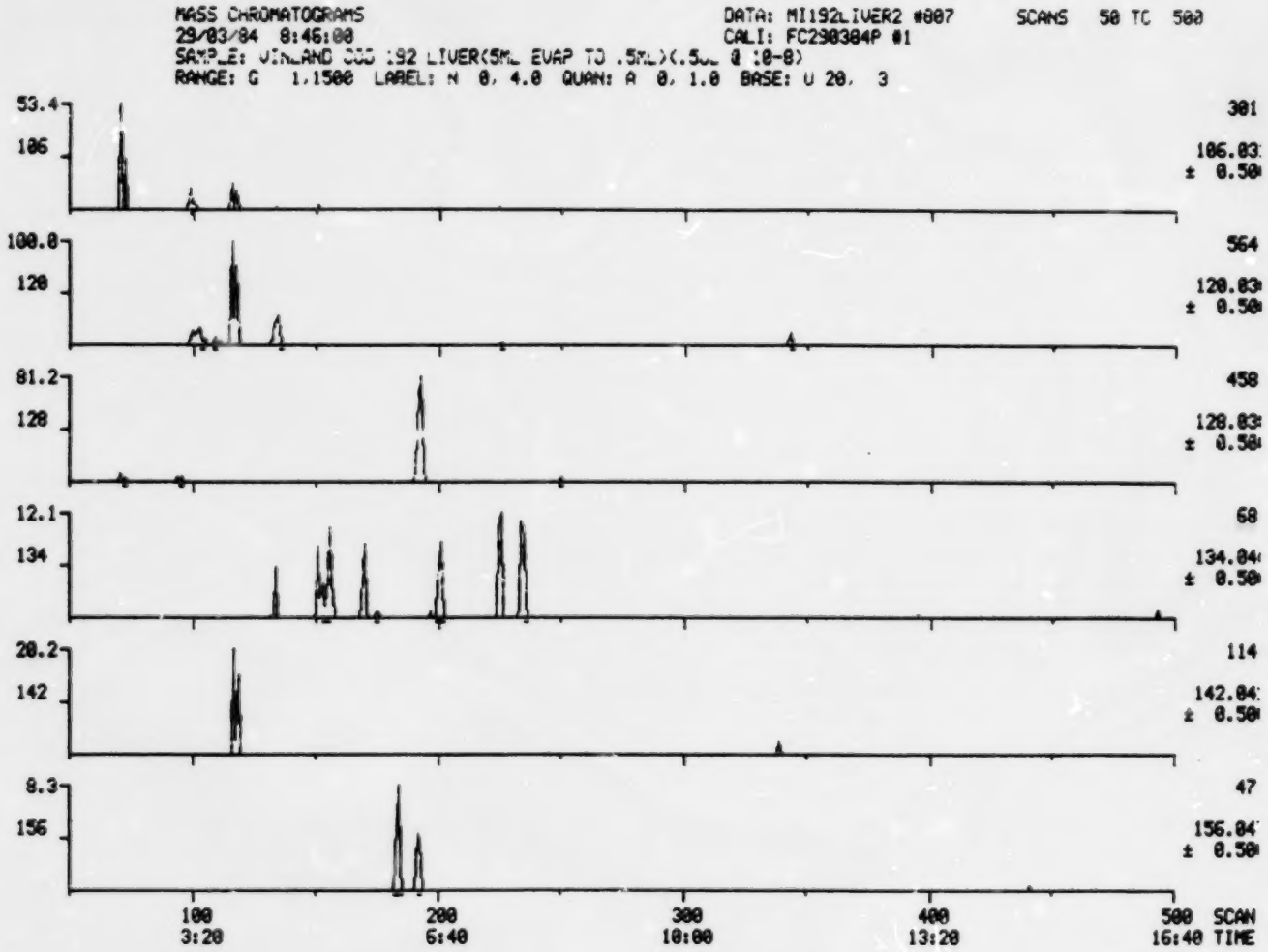

Fig. 9. Indicator hydrocarbon profile, cod #192 liver.
X-axis: scan numbers and times
Y-axes: intensity of ions normalized to the most intense peak (see absolute intensities on the right);
m/z 106 dimethylbenzenes; m/z 120 trimethylbenzenes; m/z 128 naphthalene; m/z 134 tetramethylbenzenes;
m/z 142 1- and 2-methylnaphthalene; m/z 156 dimethylnaphthalenes.

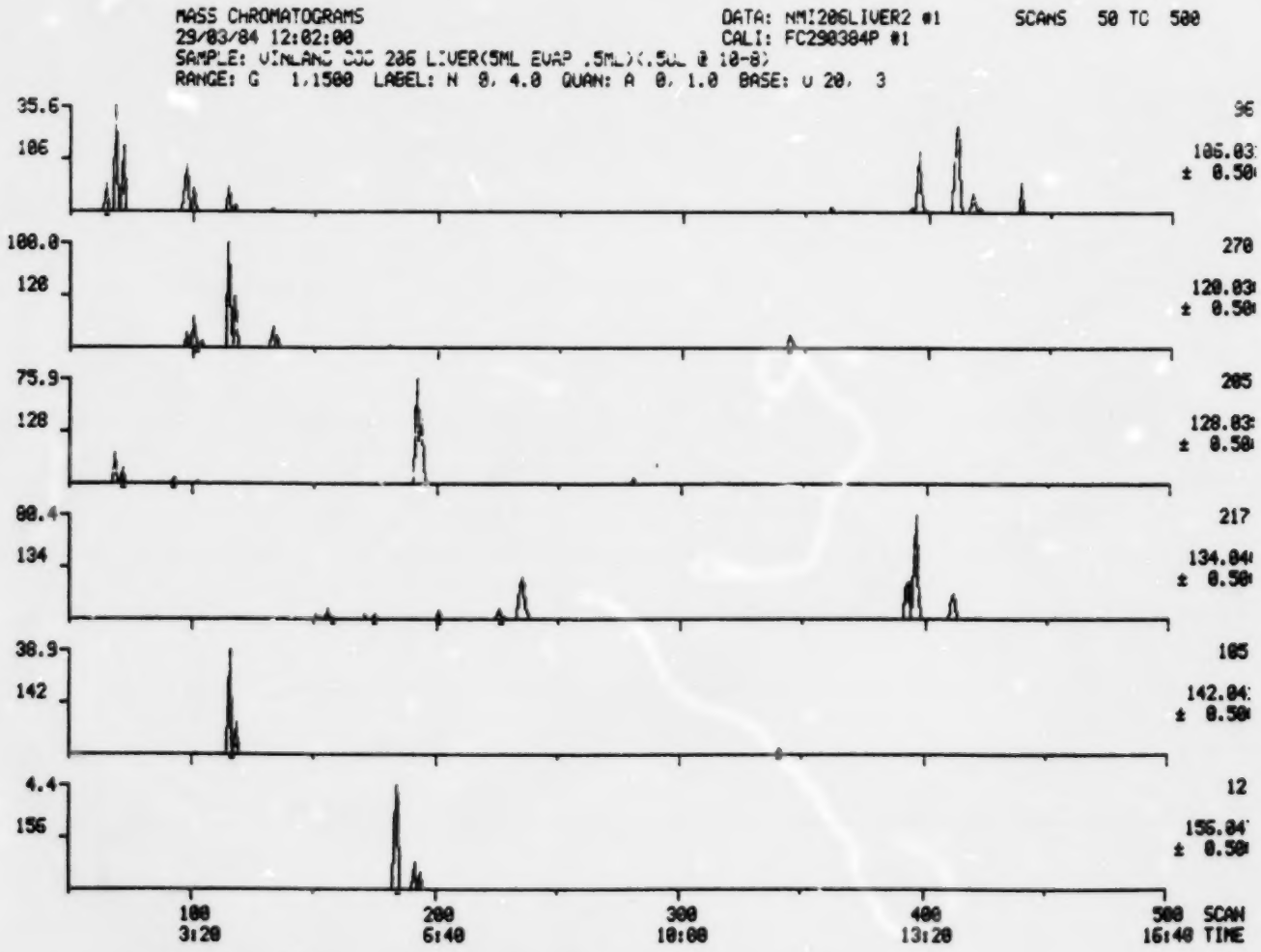

Fig. 10. Indicator hydrocarbon profile, cod #206 liver.
X-axis: scan numbers and times
Y-axes: intensity of ions normalized to the most intense peak (see absolute intensities on the right);
m/z 106 dimethylbenzenes; m/z 120 trimethylbenzenes; m/z 128 naphthalene; m/z 134 tetramethylbenzenes;
m/z 142 1- and 2-methylnaphthalene; m/z 156 dimethylnaphthalenes.

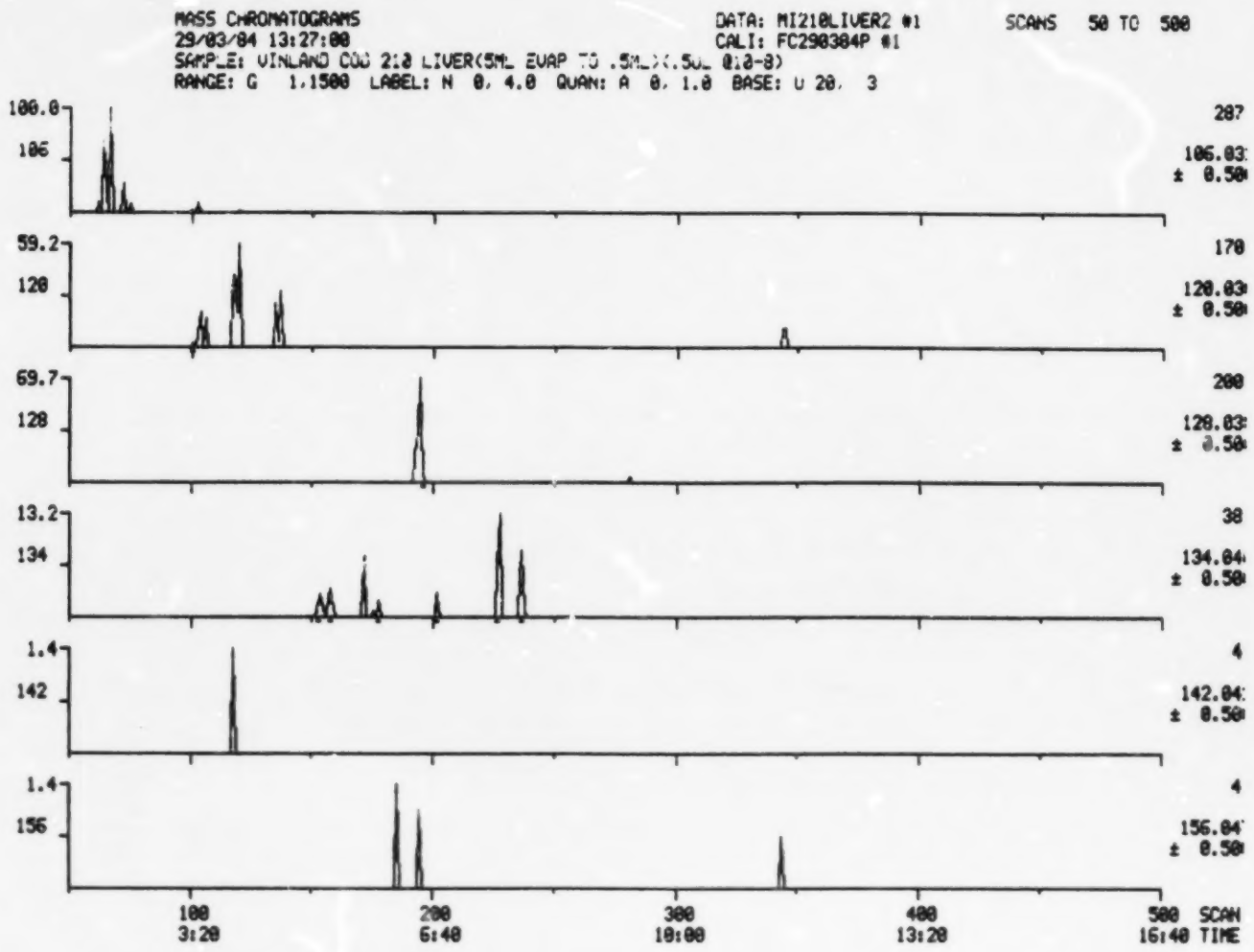

Fig. 11. Indicator hydrocarbon profile, cod #210 liver.
X-axis: scan numbers and times
Y-axes: intensity of ions normalized to the most intense peak (see absolute intensities on the right);
m/z 106 dimethylbenzenes; m/z 120 trimethylbenzenes; m/z 128 naphthalene; m/z 134 tetramethylbenzenes;
m/z 142 1- and 2-methylnaphthalene; m/z 156 dimethylnaphthalenes.

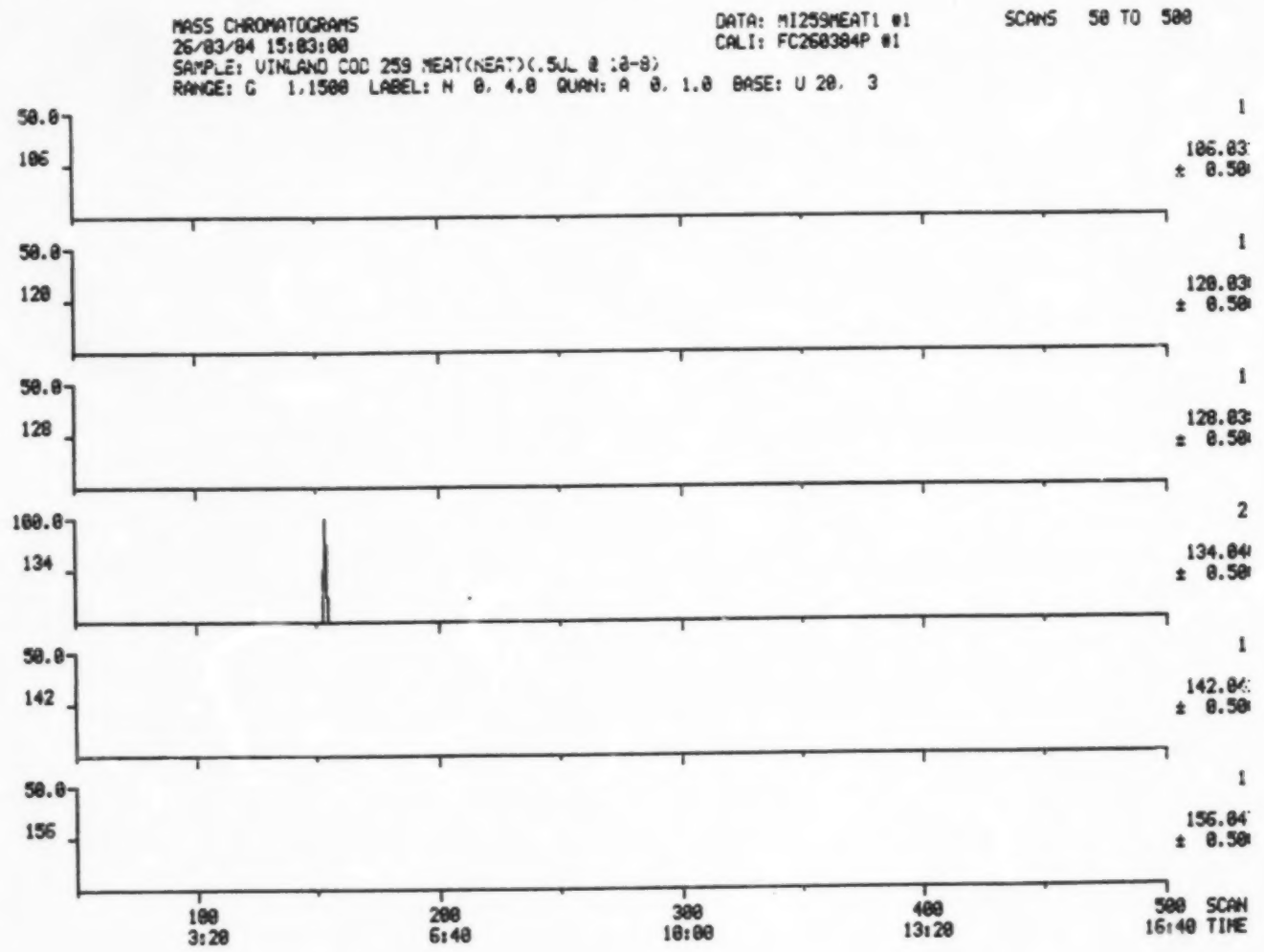

Fig. 12. Indicator hydrocarbon profile, cod #259 fillet.
X-axis: scan numbers and times
Y-axes: intensity of ions normalized to the most intense peak (see absolute intensities on the right); m/z 106 dimethylbenzenes; m/z 120 trimethylbenzenes; m/z 128 naphthalene; m/z 134 tetramethylbenzenes; m/z 142 1- and 2-methylnaphthalene; m/z 156 dimethylnaphthalenes.

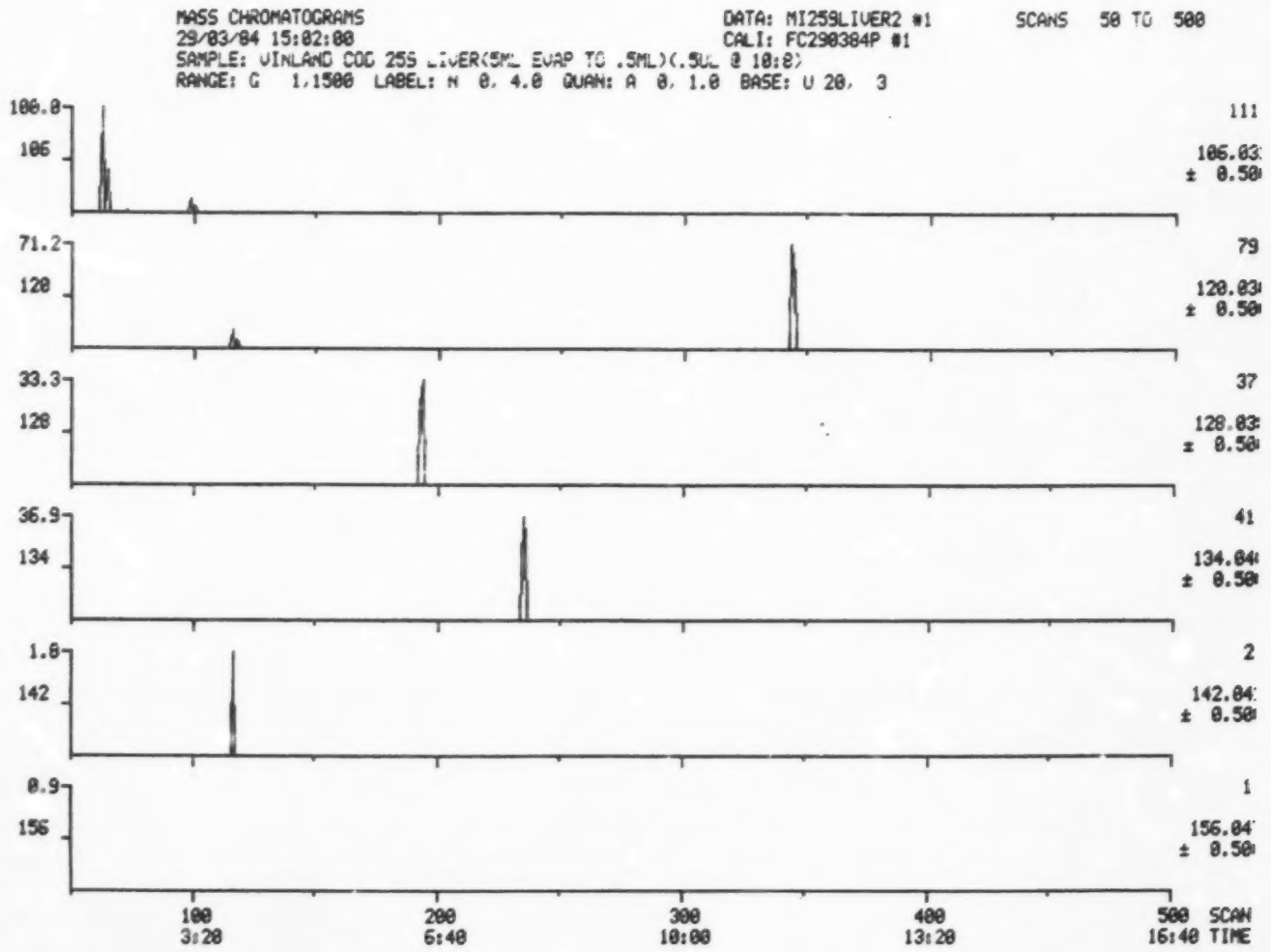

Fig. 13. Indicator hydrocarbon profile, cod #259 liver.
X-axis: scan numbers and times
Y-axes: intensity of ions normalized to the most intense peak (see absolute intensities on the right);
m/z 106 dimethylbenzenes; m/z 120 trimethylbenzenes; m/z 128 naphthalene; m/z 134 tetramethylbenzenes;
m/z 142 1- and 2-methylnaphthalene; m/z 156 dimethylnaphthalenes.

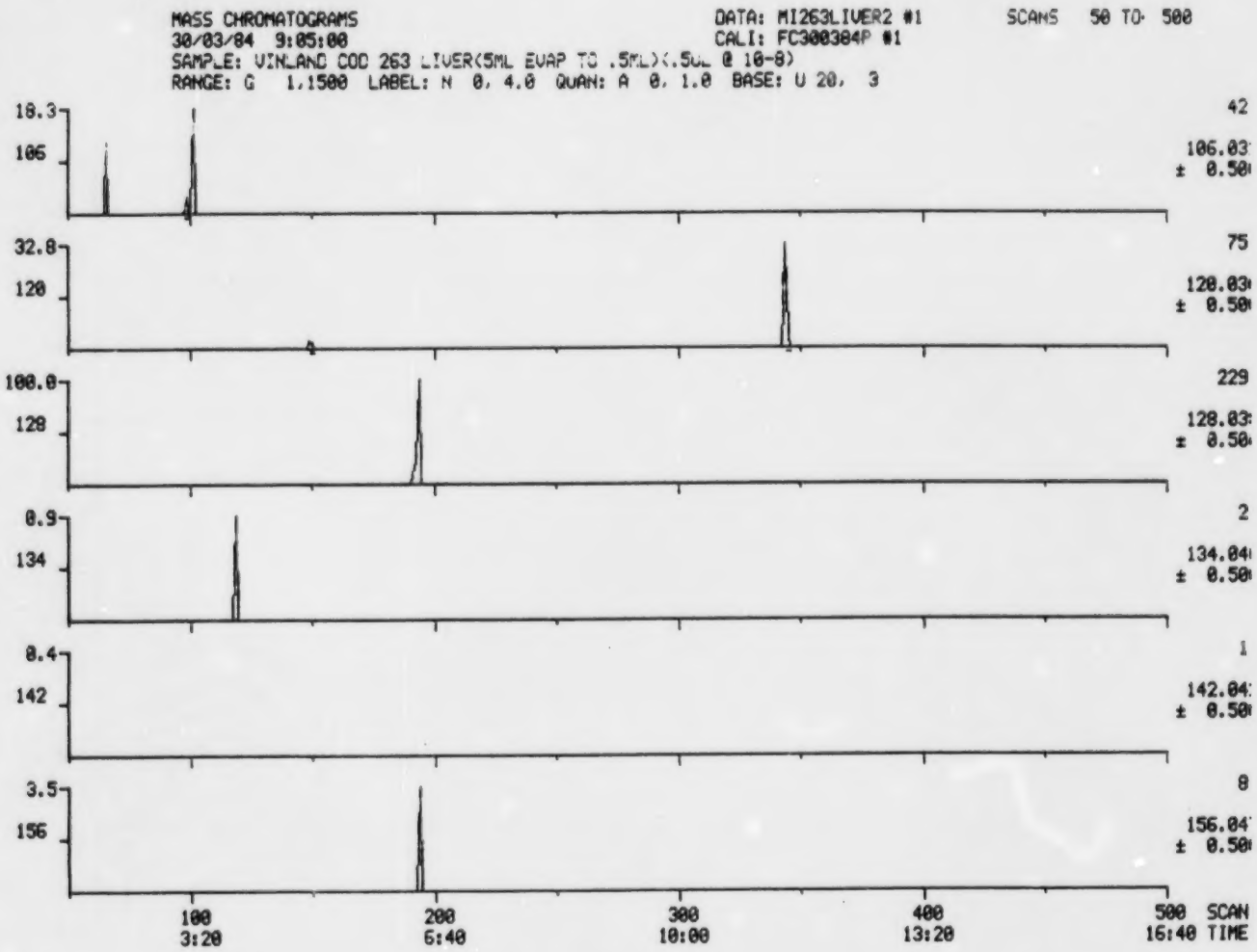

Fig. 14. Indicator hydrocarbon profile, cod #263 liver.
X-axis: scan numbers and times
Y-axes: intensity of ions normalized to the most intense peak (see absolute intensities on the right);
m/z 106 dimethylbenzenes; m/z 120 trimethylbenzenes; m/z 128 naphthalene; m/z 134 tetramethylbenzenes;
m/z 142 1- and 2-methylnaphthalene; m/z 156 dimethylnaphthalenes.

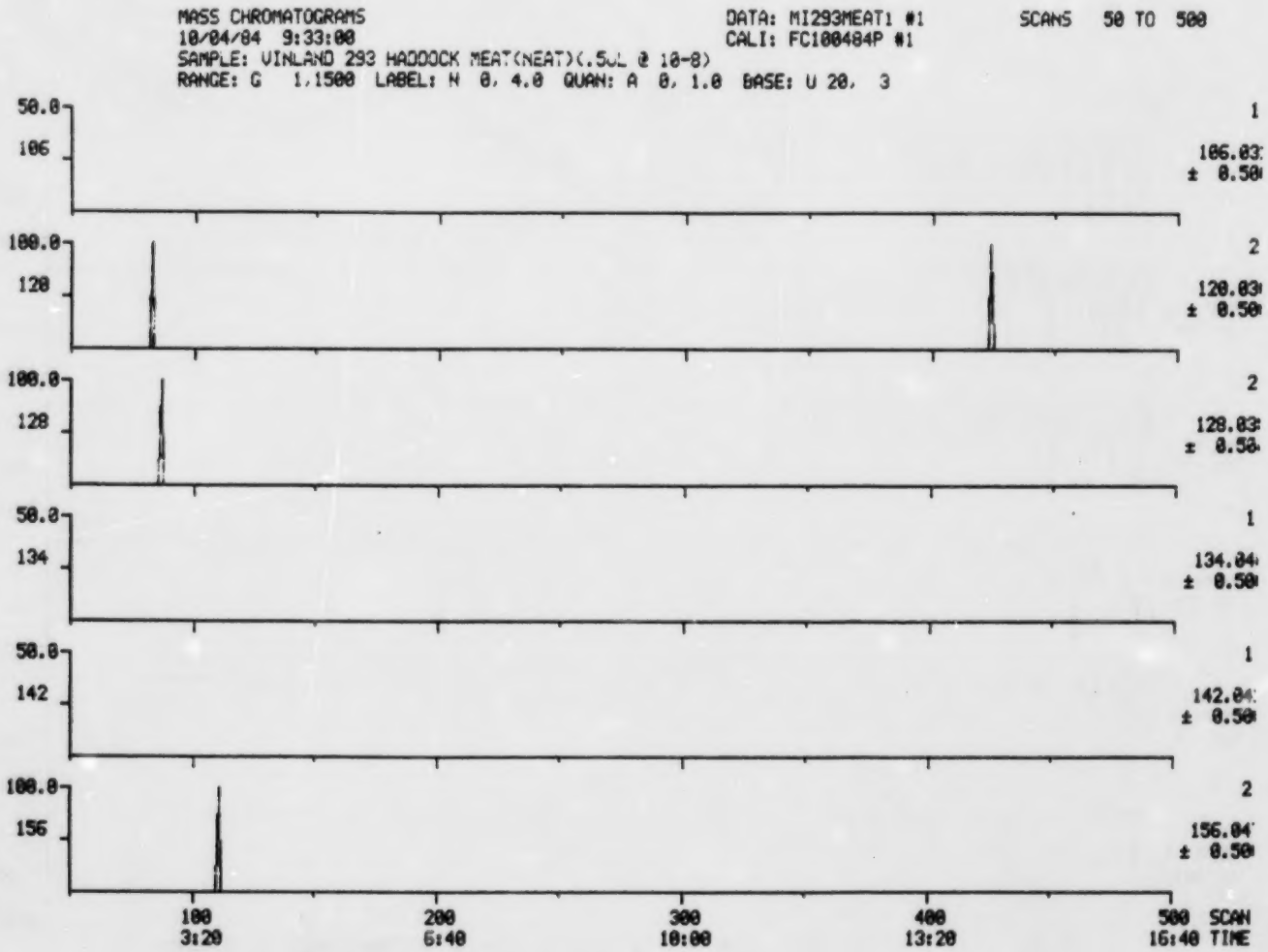

Fig. 15. Indicator hydrocarbon profile, haddock #293 fillet.
X-axis: scan numbers and times
Y-axes: intensity of ions normalized to the most intense peak (see absolute intensities on the right);
m/z 106 dimethylbenzenes; m/z 120 trimethylbenzenes; m/z 128 naphthalene; m/z 134 tetramethylbenzenes;
m/z 142 1- and 2-methylnaphthalene; m/z 156 dimethylnaphthalenes.

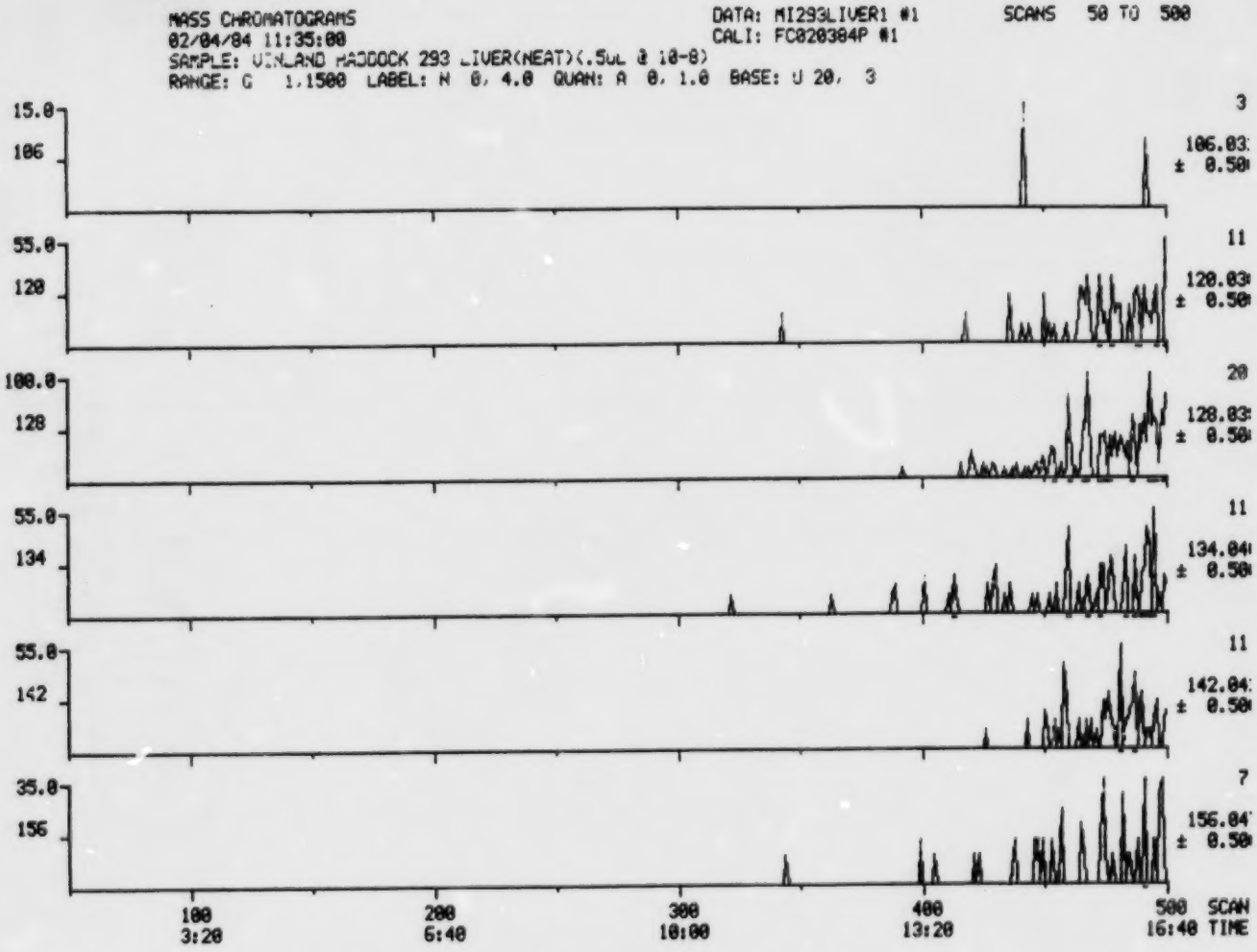

Fig. 16. Indicator hydrocarbon profile, haddock #293 liver.
X-axis: scan numbers and times
Y-axes: intensity of ions normalized to the most intense peak (see absolute intensities on the right);
m/z 106 dimethylbenzenes; m/z 120 trimethylbenzenes; m/z 128 naphthalene; m/z 134 tetramethylbenzenes;
m/z 142 1- and 2-methylnaphthalene; m/z 156 dimethylnaphthalenes.

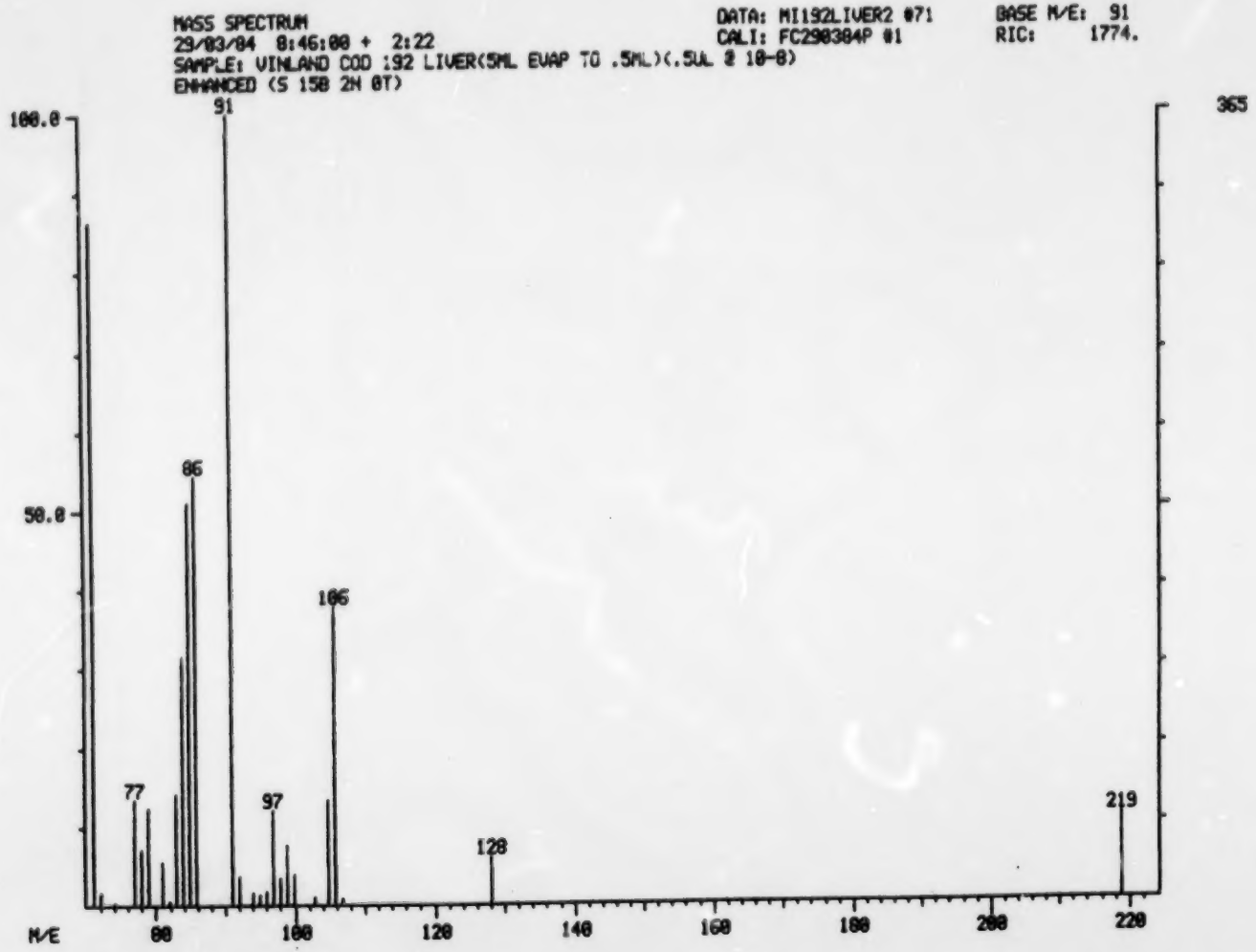

Fig. 17. Mass spectrum of cod #192 liver; scan 71.
X-axis: m/z units
Y-axis: relative intensity (left), absolute intensity (right).
Dimethylbenzenes have a molecular ion at m/z=106. The ion at m/z=91 is formed by the loss of a methyl group.

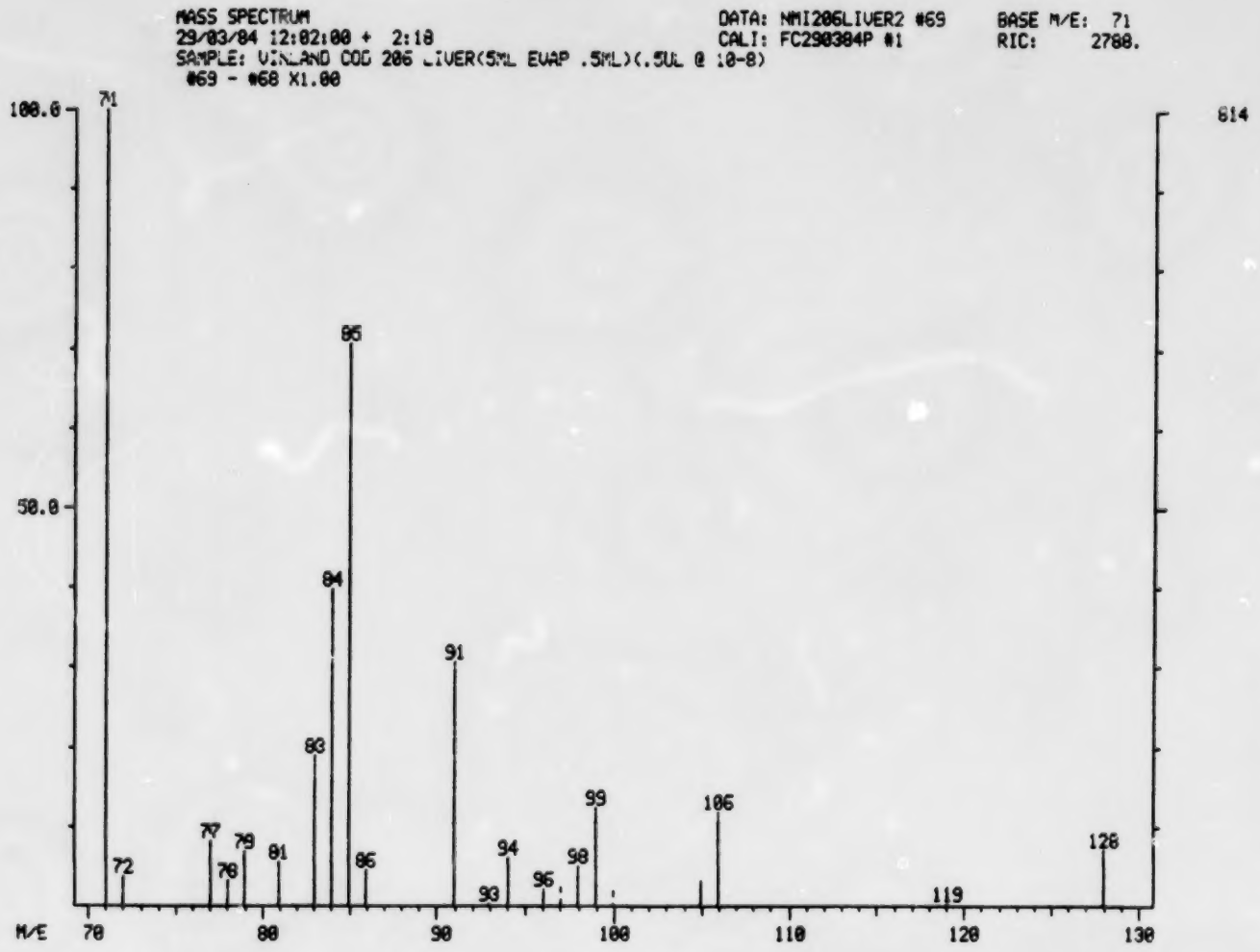

Fig. 18. Mass spectrum of cod #206 liver; scan 69.
X-axis: m/z units
Y-axis: relative intensity (left), absolute intensity (right).

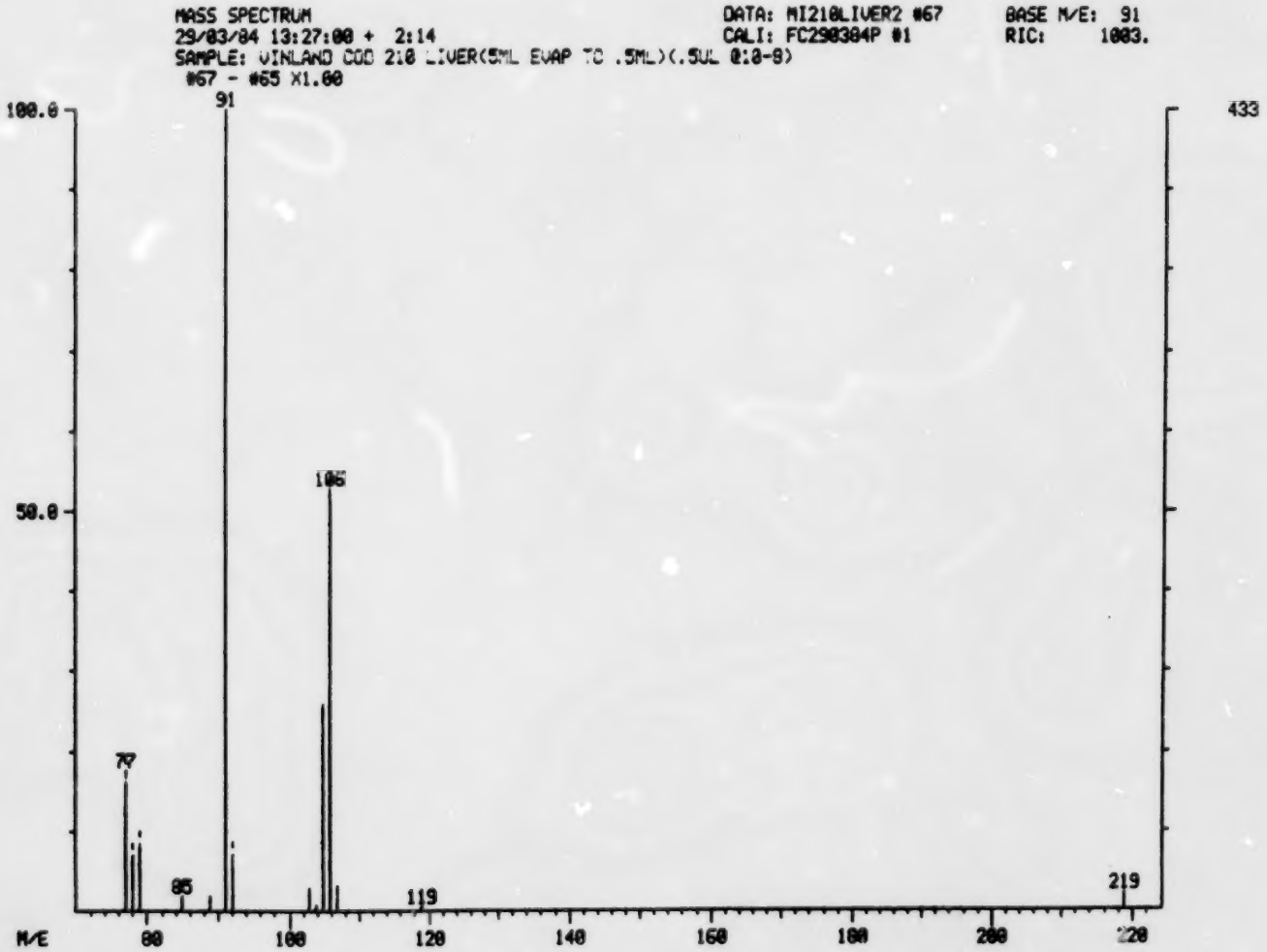

Fig. 19. Mass spectrum of cod #210 liver; scan 67.
X-axis: m/z units
Y-axis: relative intensity (left), absolute intensity (right).

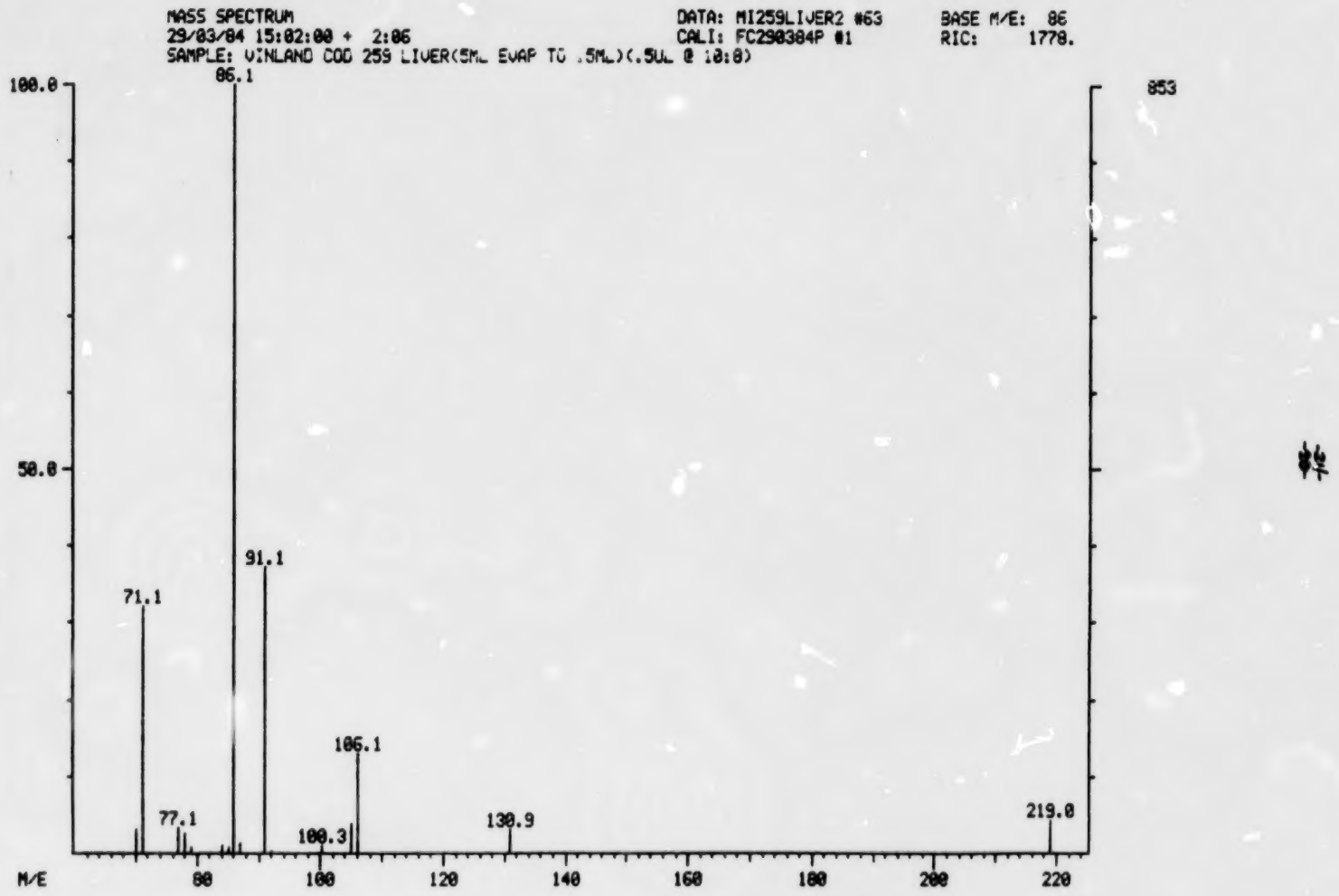

Fig. 20. Mass spectrum of cod #259 liver; scan 63.
X-axis: m/z units
Y-axis: relative intensity (left), absolute intensity (right).

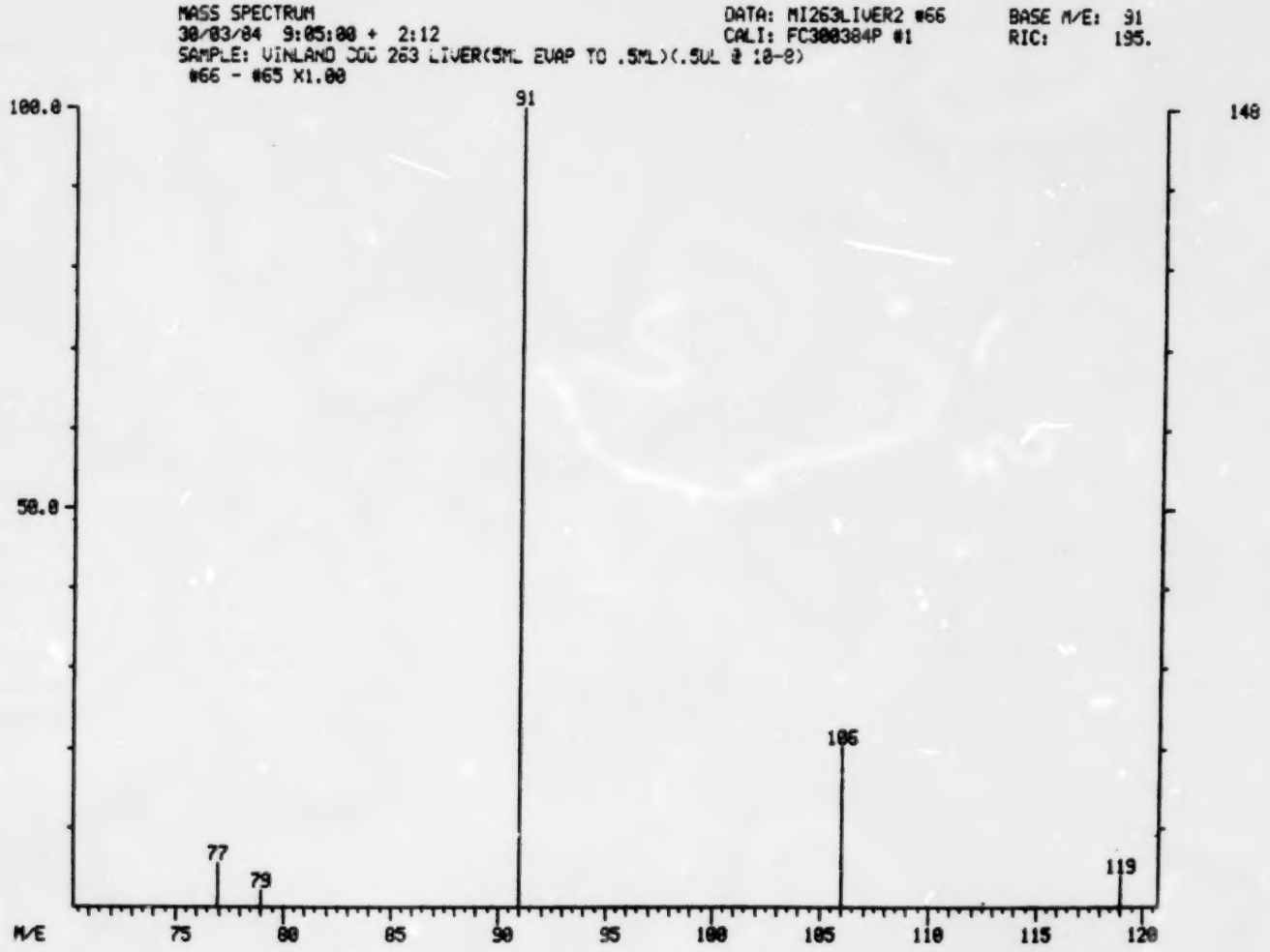

Fig. 21. Mass spectrum of cod #263 liver; scan 66.
X-axis: m/z units
Y-axis: relative intensity (left), absolute intensity (right).

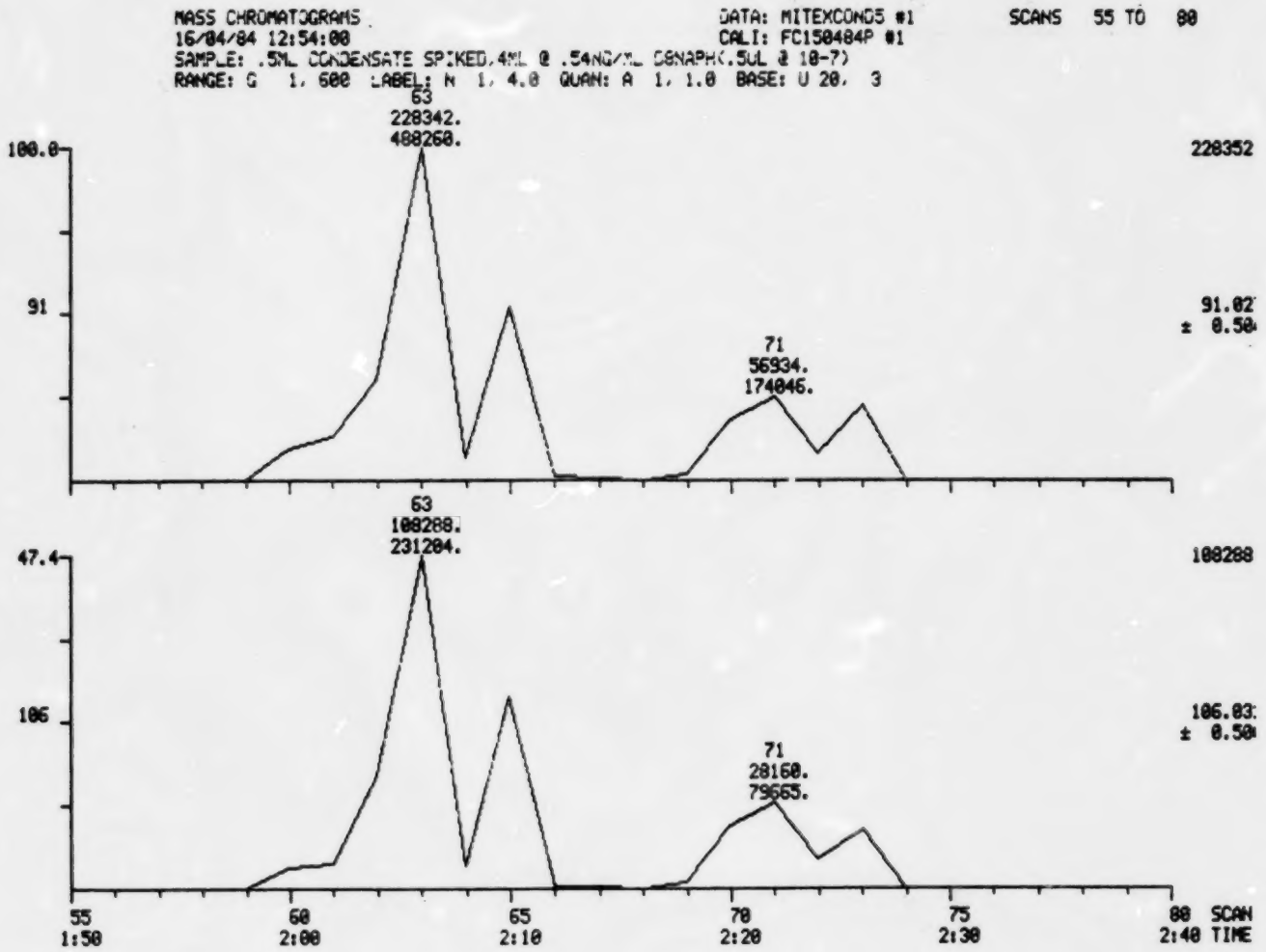

Fig. 22. Dimethylbenzenes indicator profile m/z=106 and 91. Gas condensate. Identity of peaks as yet unknown.
X-axis: scan numbers and times
Y-axes: intensity of ions normalized to the most intense peak (see absolute intensities on the right).

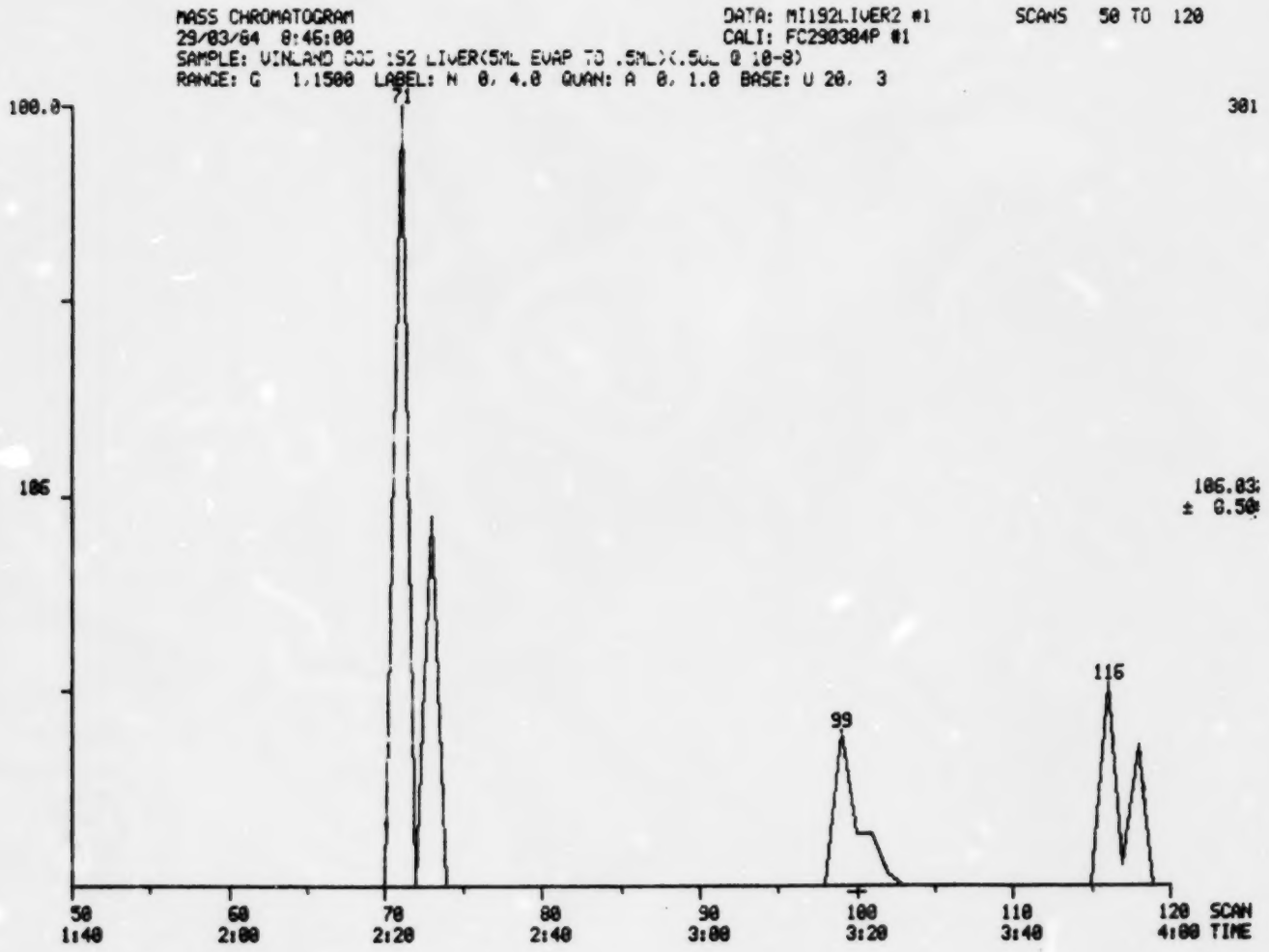

Fig. 23. Dimethylbenzenes indicator profile m/z=106. Cod #192 liver.
X-axis: scan numbers and times
Y-axes: intensity of ions normalized to the most intense peak (see absolute intensities on the right).

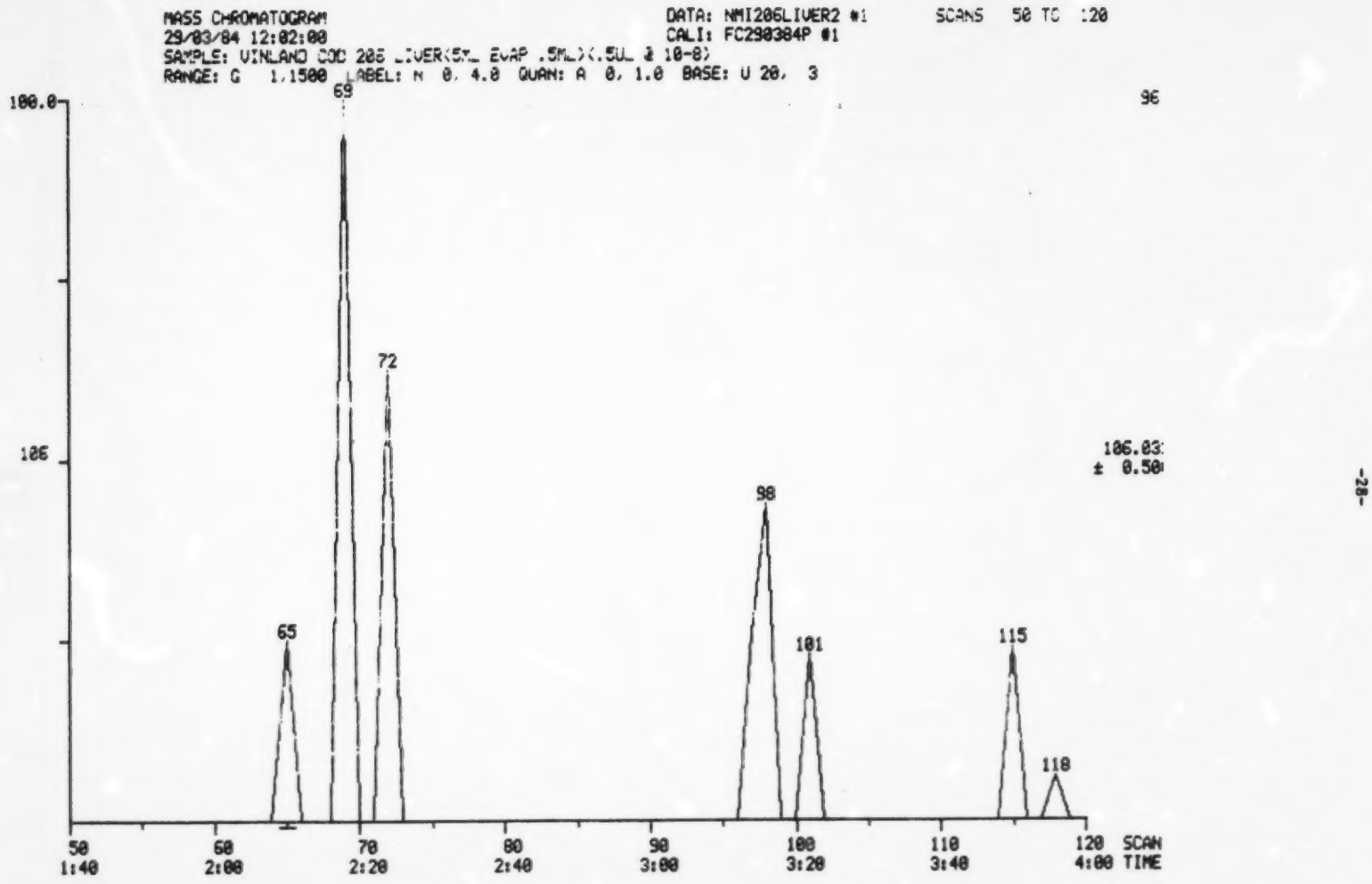

Fig. 24. Dimethylbenzenes indicator profile m/z=106. Cod #206 liver.
X-axis: scan numbers and times
Y-axes: intensity of ions normalized to the most intense peak (see absolute intensities on the right).

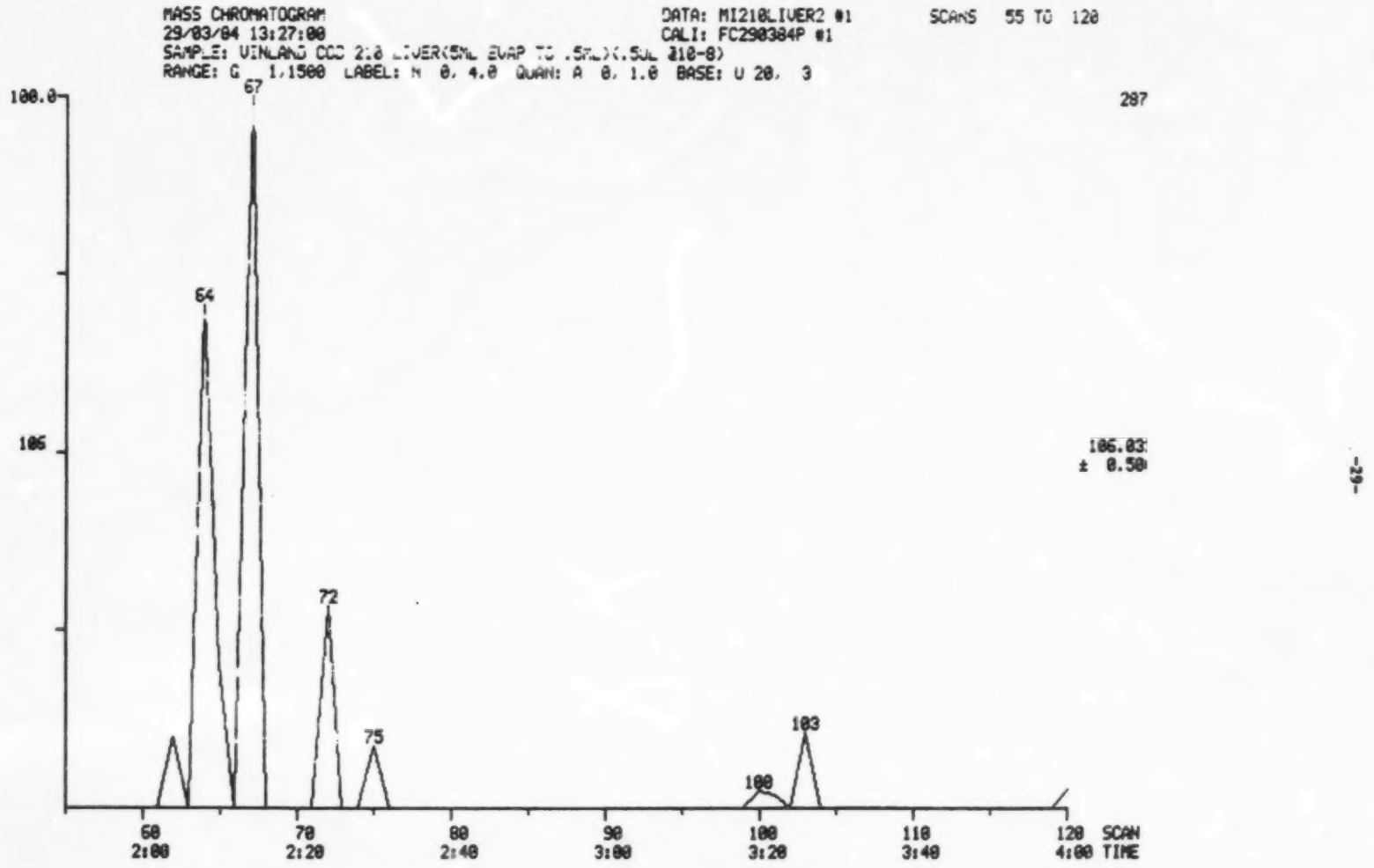

Fig. 25. Dimethylbenzenes indicator profile m/z=106. Cod #210 liver.
X-axis: scan numbers and times
Y-axes: intensity of ions normalized to the most intense peak (see absolute intensities on the right).

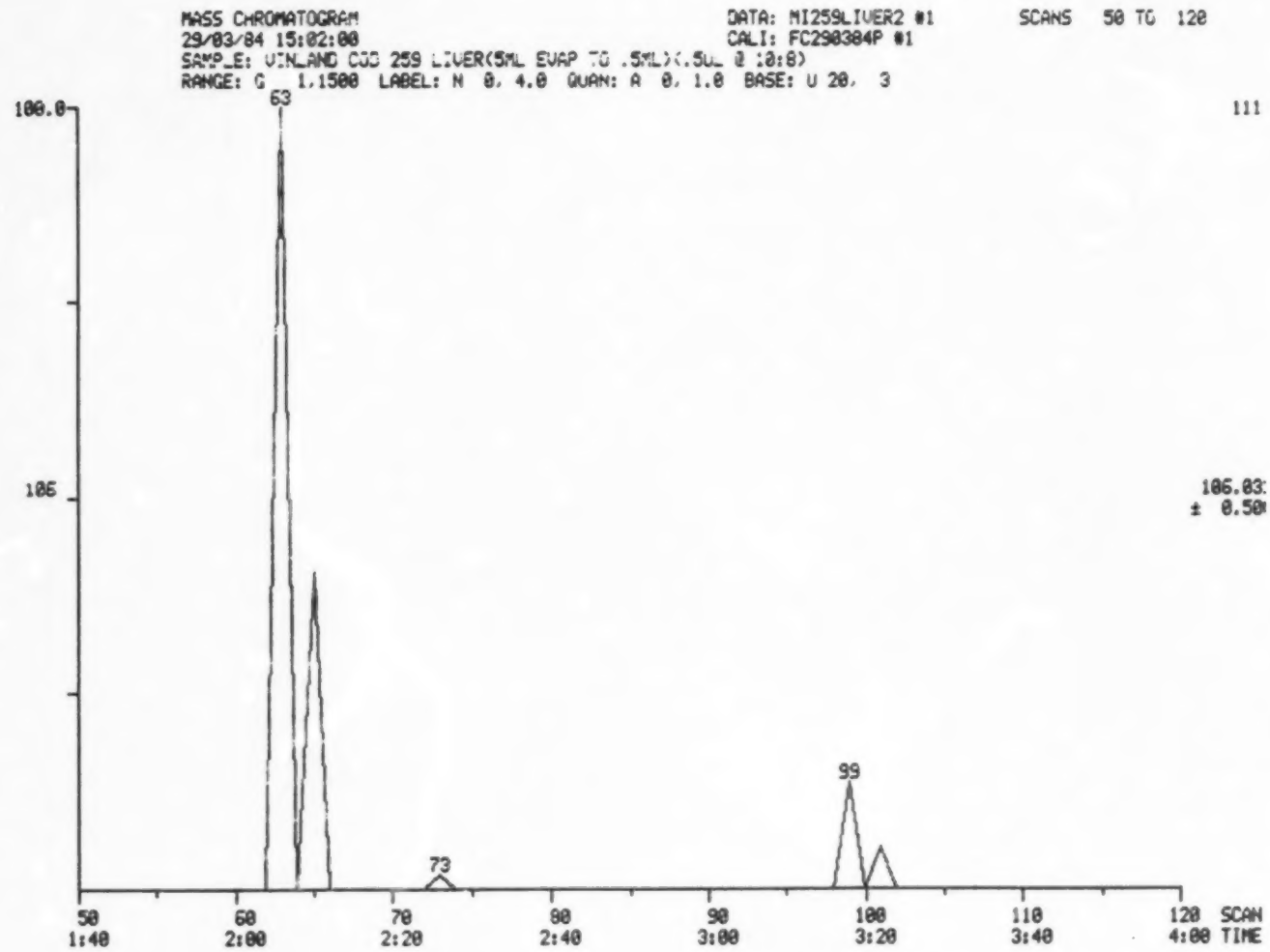

Fig. 26. Dimethylbenzenes indicator profile m/z=106. Cod #259 liver.
X-axis: scan numbers and times
Y-axes: intensity of ions normalized to the most intense peak (see absolute intensities on the right).

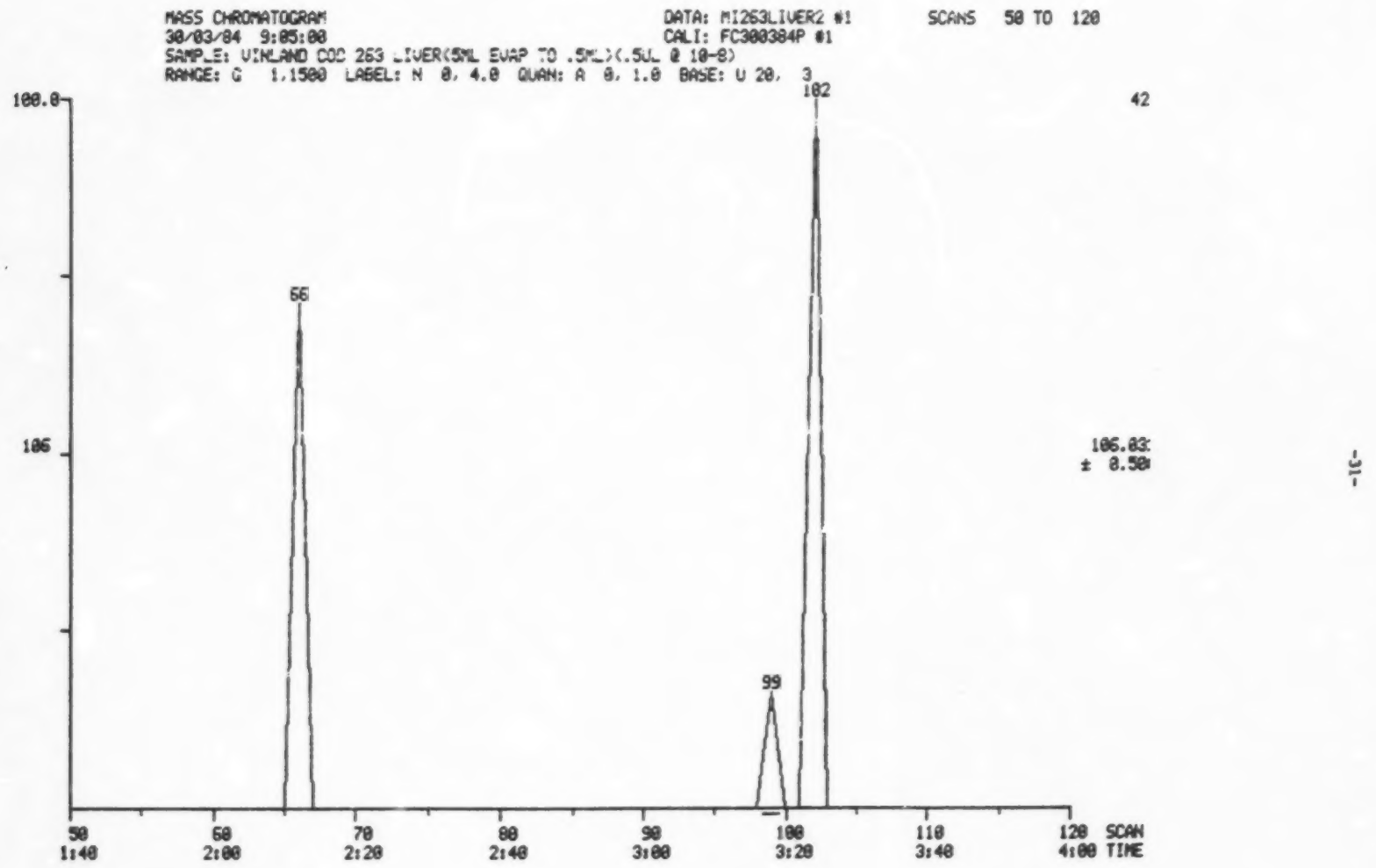

Fig. 27. Dimethylbenzenes indicator profile m/z=106. Cod #263 liver.
X-axis: scan numbers and times
Y-axes: intensity of ions normalized to the most intense peak (see absolute intensities on the right).

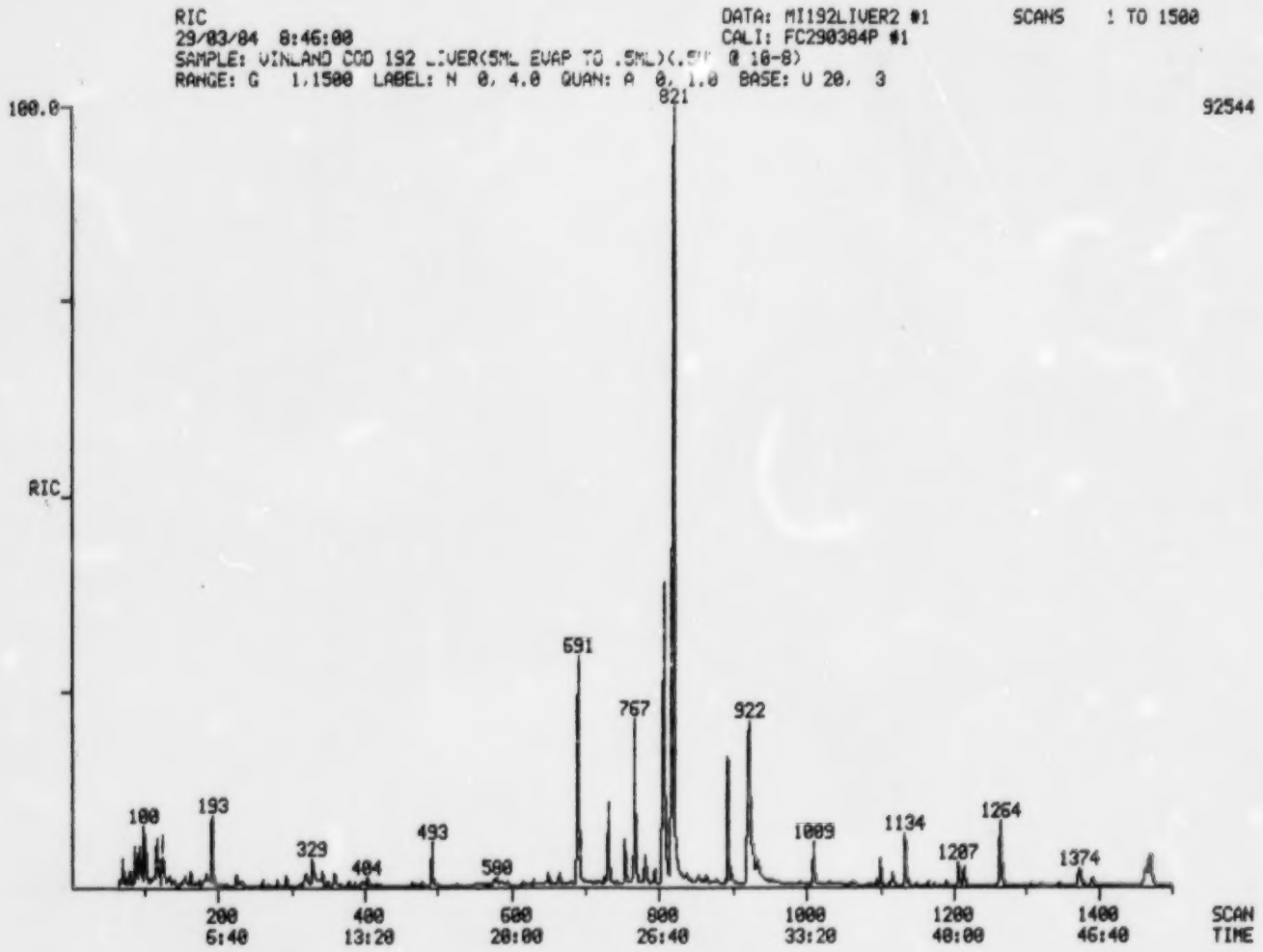

Fig. 28. Reconstructed gas chromatogram of cod #192 liver.
X-axis: scan numbers and times
Y-axes: intensity of ions normalized to the most intense peak (see absolute intensities on the right).
The most intense peak (scan 821) is a hexadecanoic acid. For additional details see text.

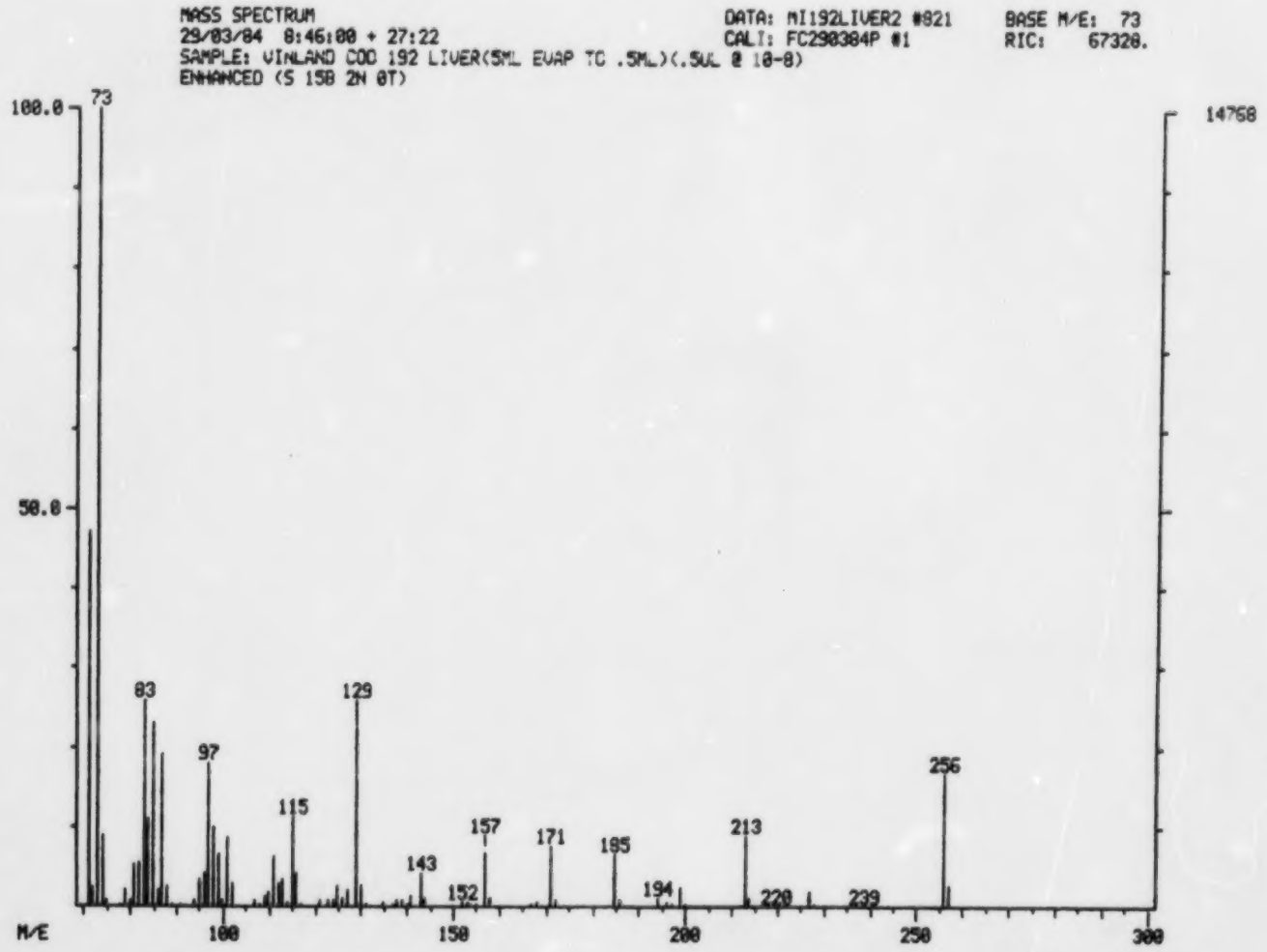

Fig. 29. Mass spectrum of cod #192 liver, scan 821.
X-axis: m/z units
Y-axis: relative intensity (left), absolute intensity (right). Tentatively identified as a hexadecanoic acid.

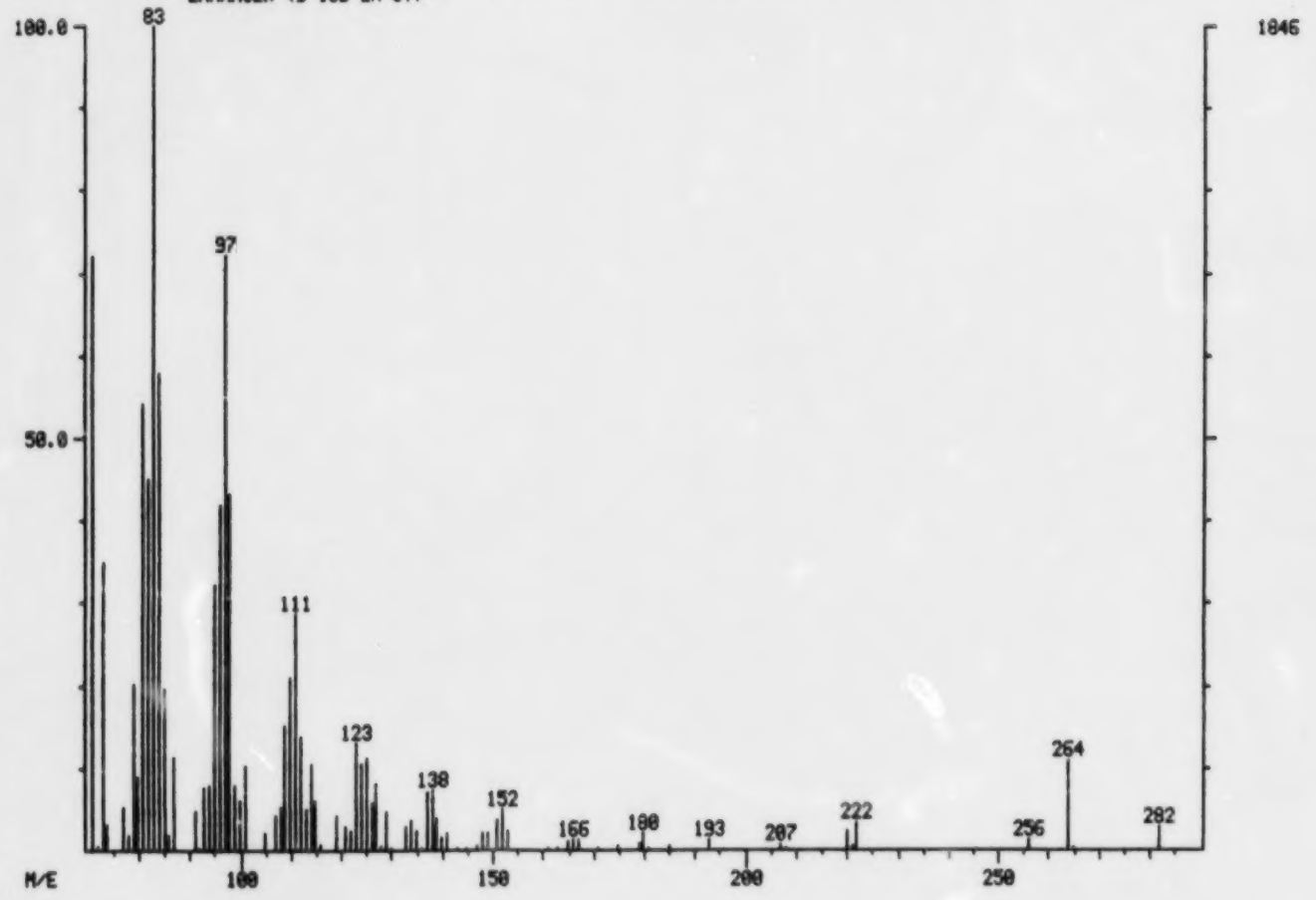

Fig. 30. Mass spectrum of cod #192 liver, scan 922.
X-axis: m/z units
Y-axis: relative intensity (left), absolute intensity (right). Tentatively identified as an alkenoic acid ester.

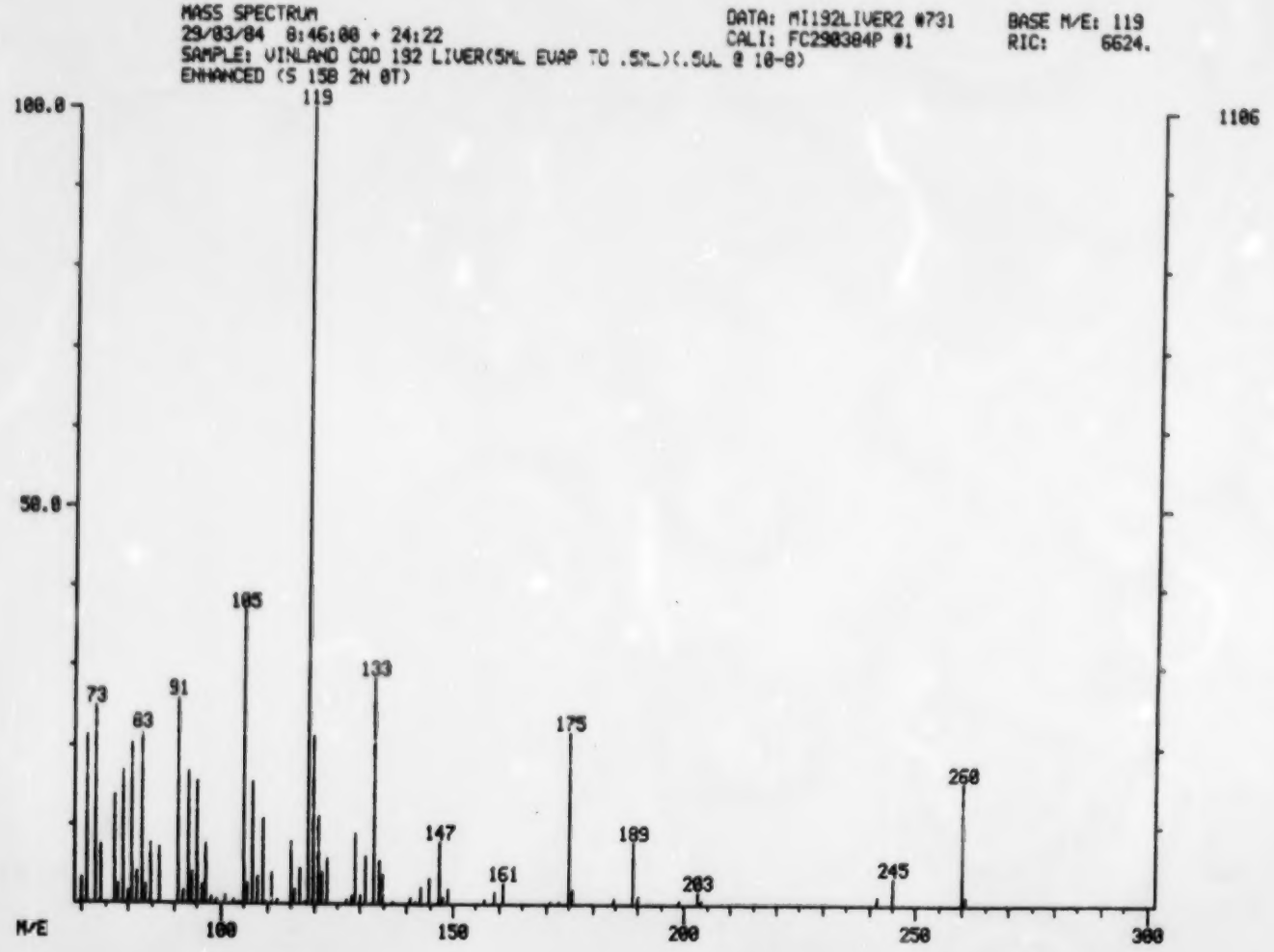

Fig. 31. Mass spectrum of cod #192 liver, scan 731.
X-axis: m/z units
Y-axis: relative intensity (left), absolute intensity (right). Ions at m/z=105, 119, and 133 indicate an alkylbenzene. If the molecular ion is at m/z=260, this compound may be a phenyltridecane.

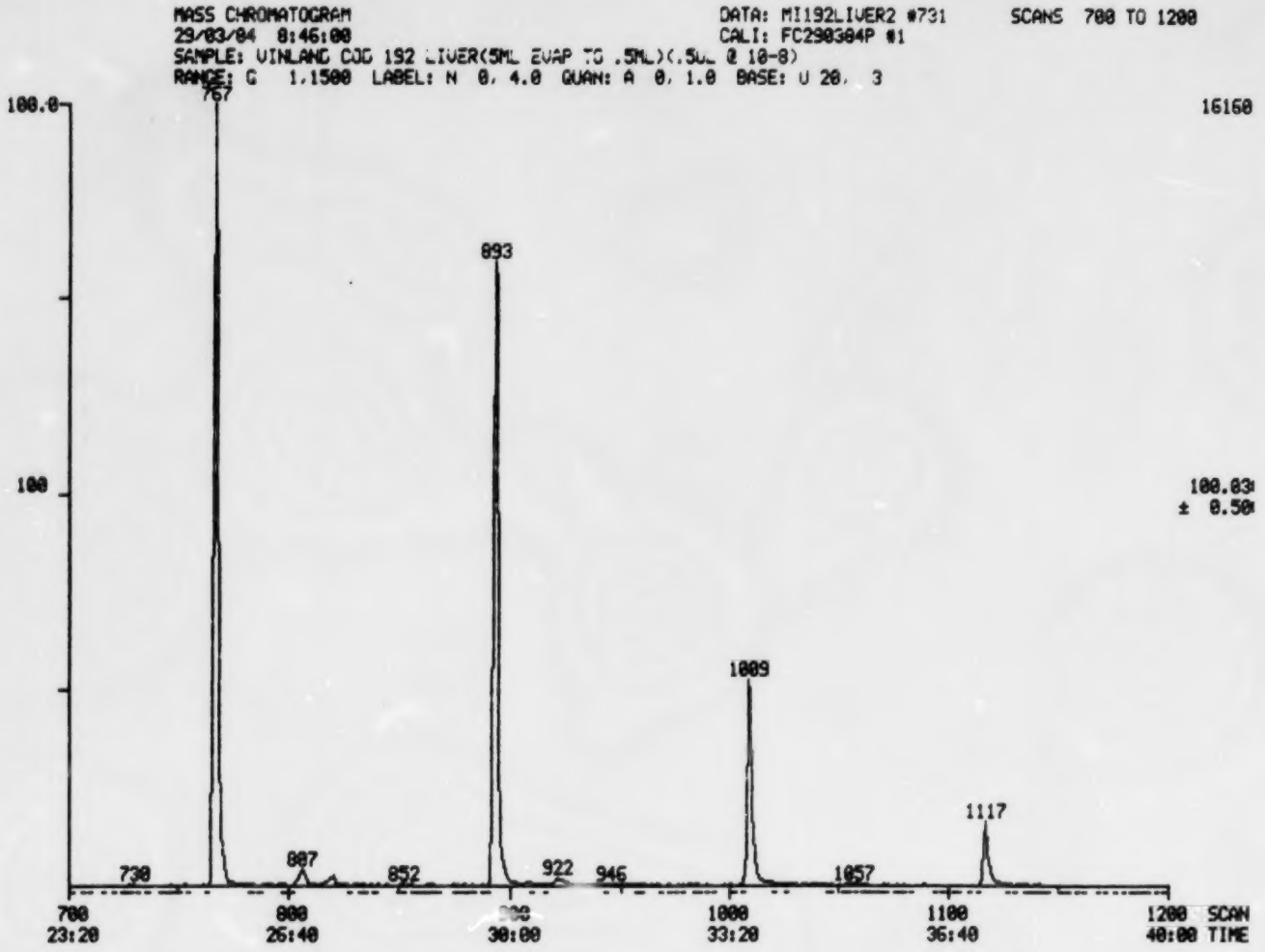

Fig. 32. Reconstructed gas chromatogram m/z=100 of cod #192 liver.
X-axis: scan numbers and times
Y-axes: intensity of ions normalized to the most intense peak (see absolute intensities on the right).

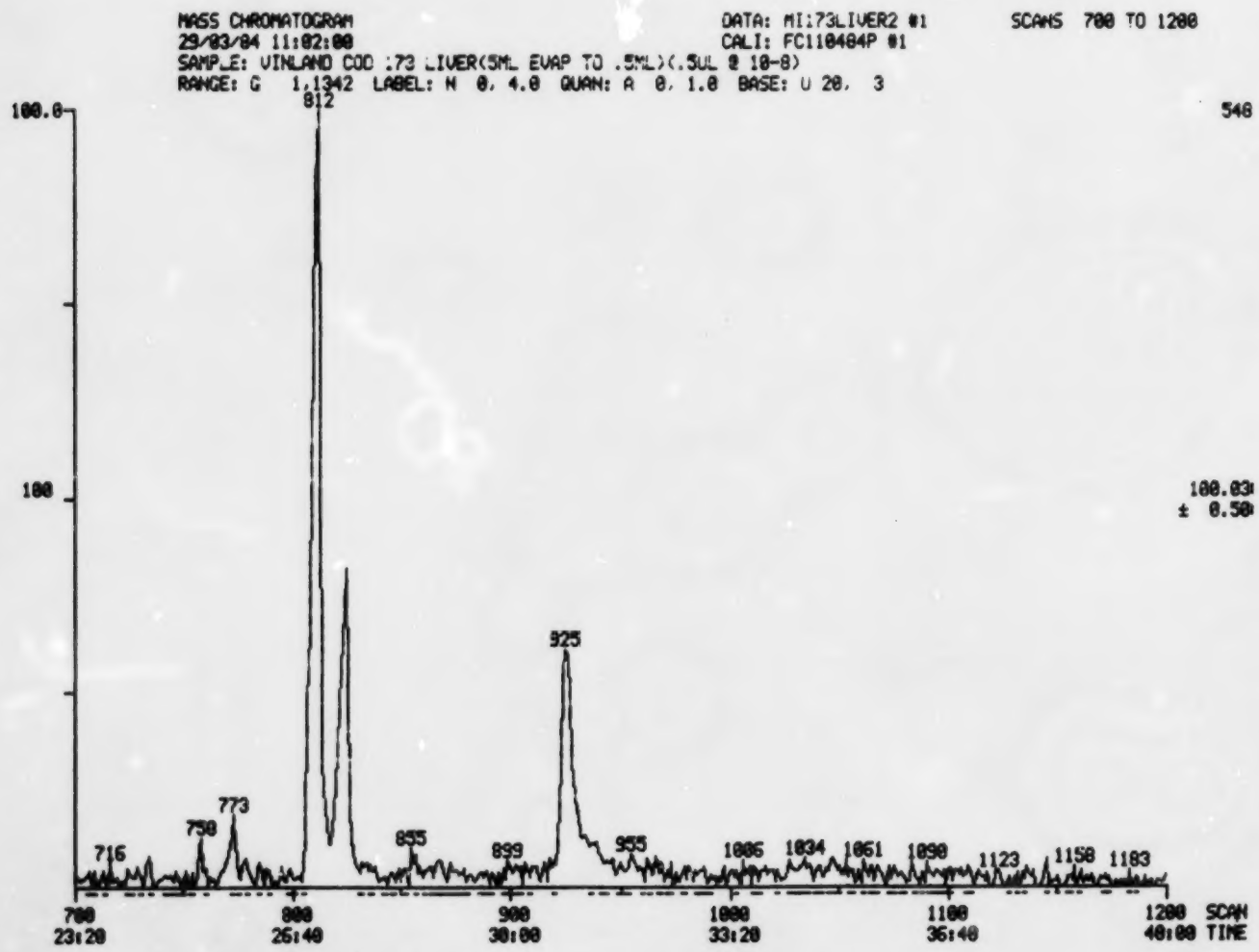

Fig. 33. Reconstructed gas chromatogram m/z=100 of cod #173 liver.
X-axis: scan numbers and times
Y-axes: intensity of ions normalized to the most intense peak (see absolute intensities on the right).

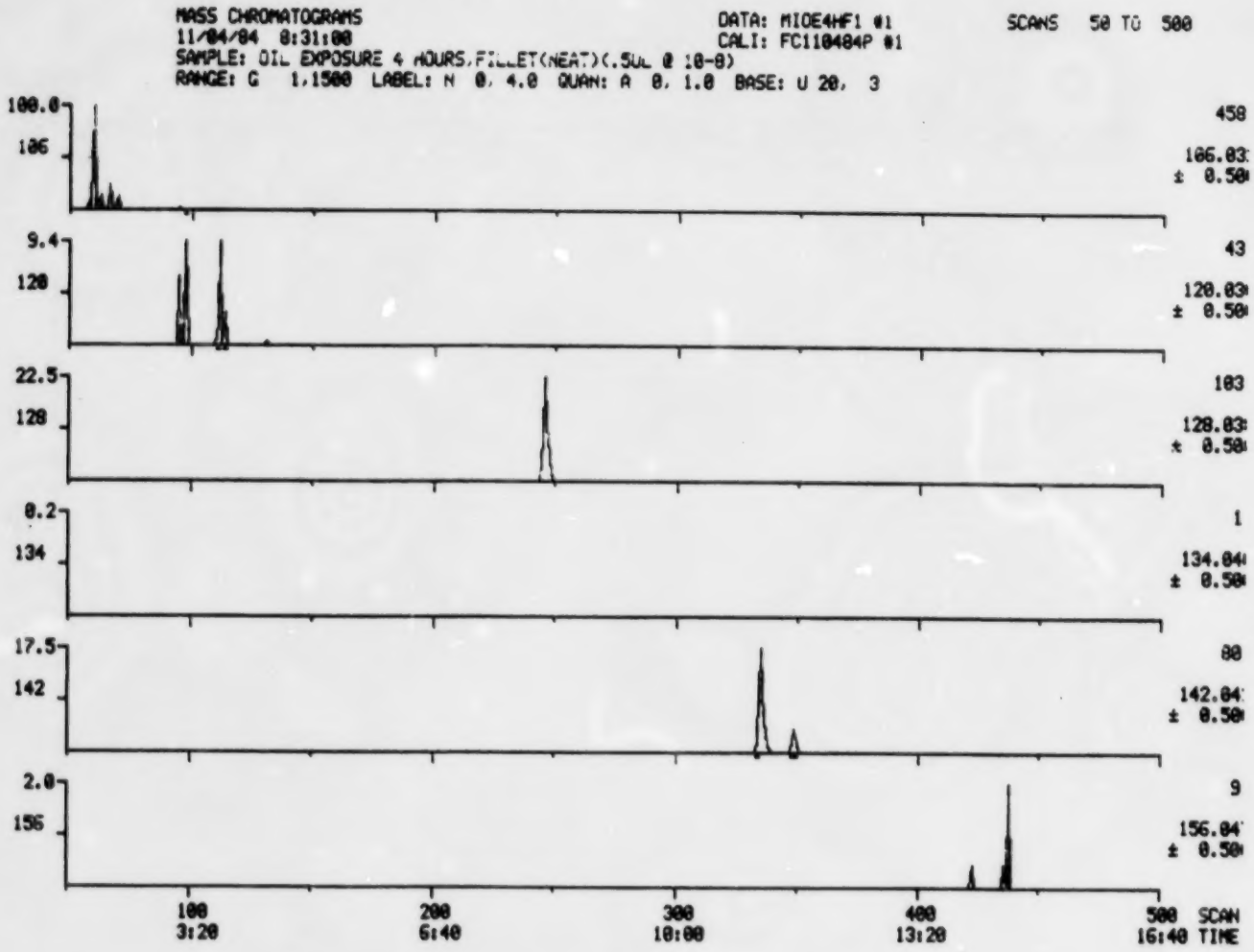

Fig. 34. Indicator hydrocarbon profile, juvenile Atlantic salmon, fillet, 4-h exposure to gas condensate.
X-axis: scan numbers and times
Y-axes: intensity of ions normalized to the most intense peak (see absolute intensities on the right).
m/z 106 dimethylbenzenes; m/z 120 trimethylbenzenes; m/z 128 naphthalene; m/z 134 tetramethylbenzenes;
m/z 142 1- and 2-methylnaphthalene; m/z 156 dimethylnaphthalenes.

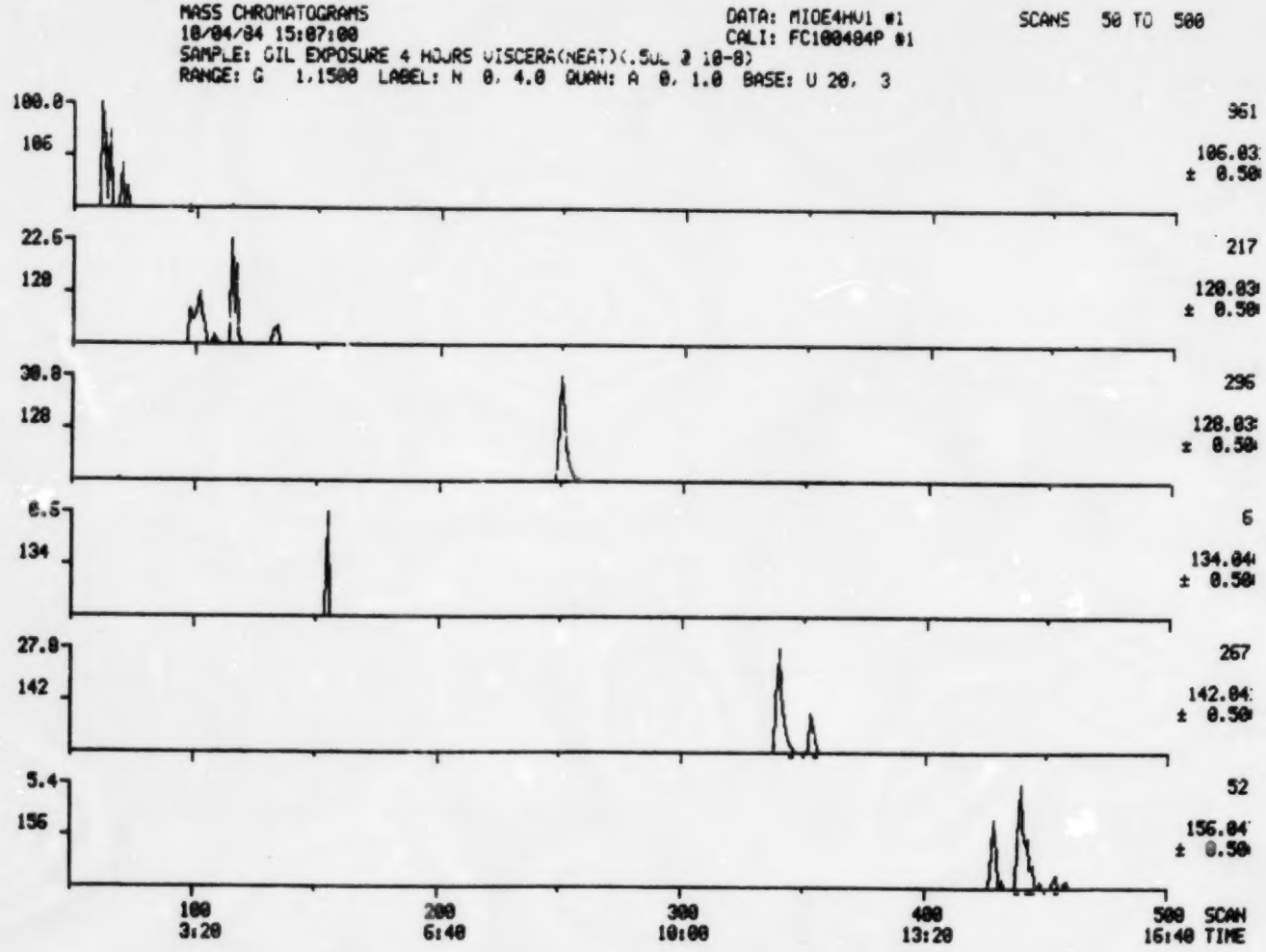

Fig. 35. Indicator hydrocarbon profile, juvenile Atlantic salmon, viscera, 4-h exposure to gas condensate.
X-axis: scan numbers and times
Y-axes: intensity of ions normalized to the most intense peak (see absolute intensities on the right).
m/z 106 dimethylbenzenes; m/z 120 trimethylbenzenes; m/z 128 naphthalene; m/z 134 tetramethylbenzenes;
m/z 142 1- and 2-methylnaphthalene; m/z 156 dimethylnaphthalenes.

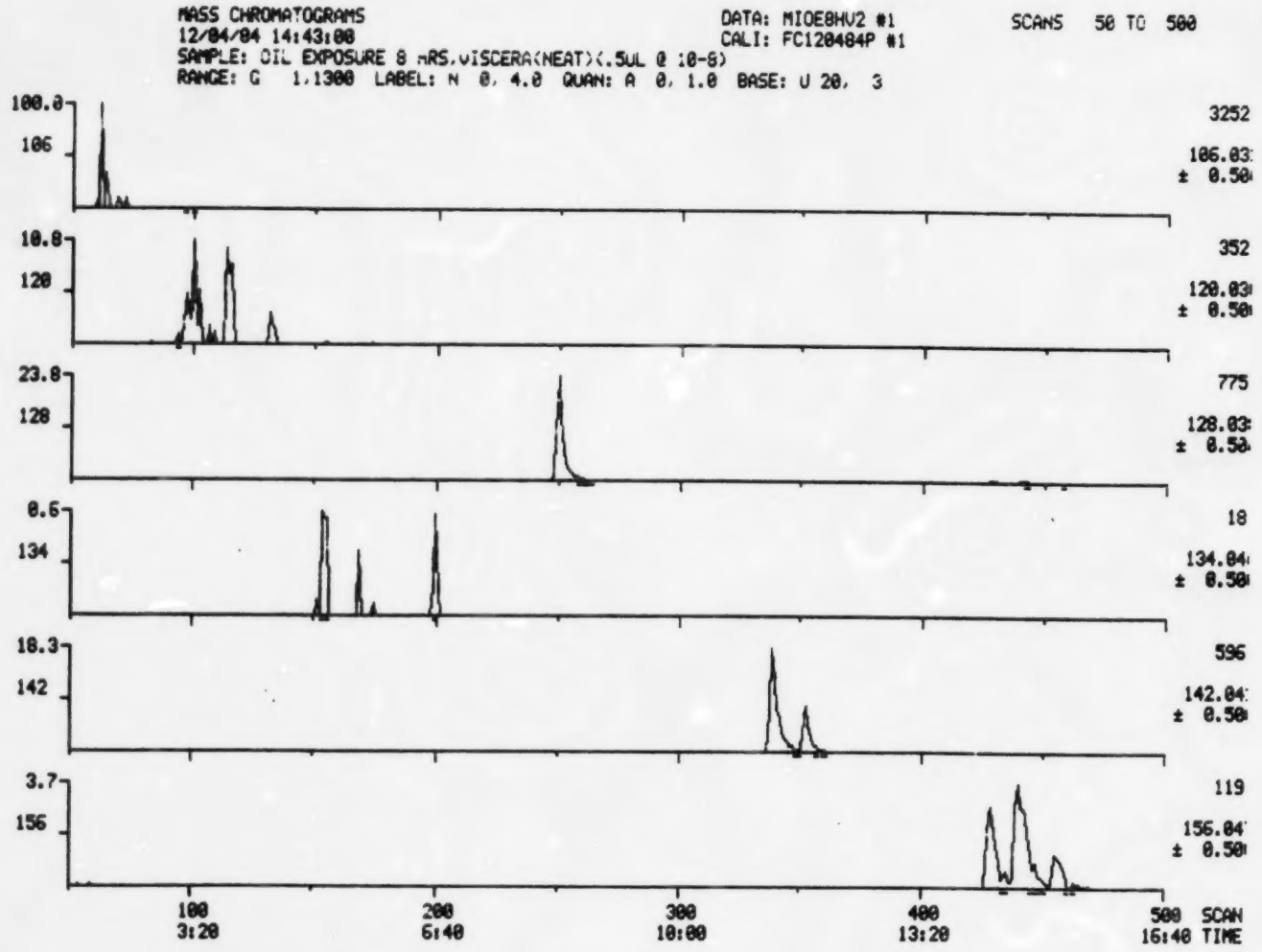

Fig. 36. Indicator hydrocarbon profile, juvenile Atlantic salmon, viscera, 8-h exposure to gas condensate.
X-axis: scan numbers and times
Y-axes: intensity of ions normalized to the most intense peak (see absolute intensities on the right).
m/z 106 dimethylbenzenes; m/z 120 trimethylbenzenes; m/z 128 naphthalene; m/z 134 tetramethylbenzenes; m/z 142 1- and 2-methylnaphthalene; m/z 156 dimethylnaphthalenes.

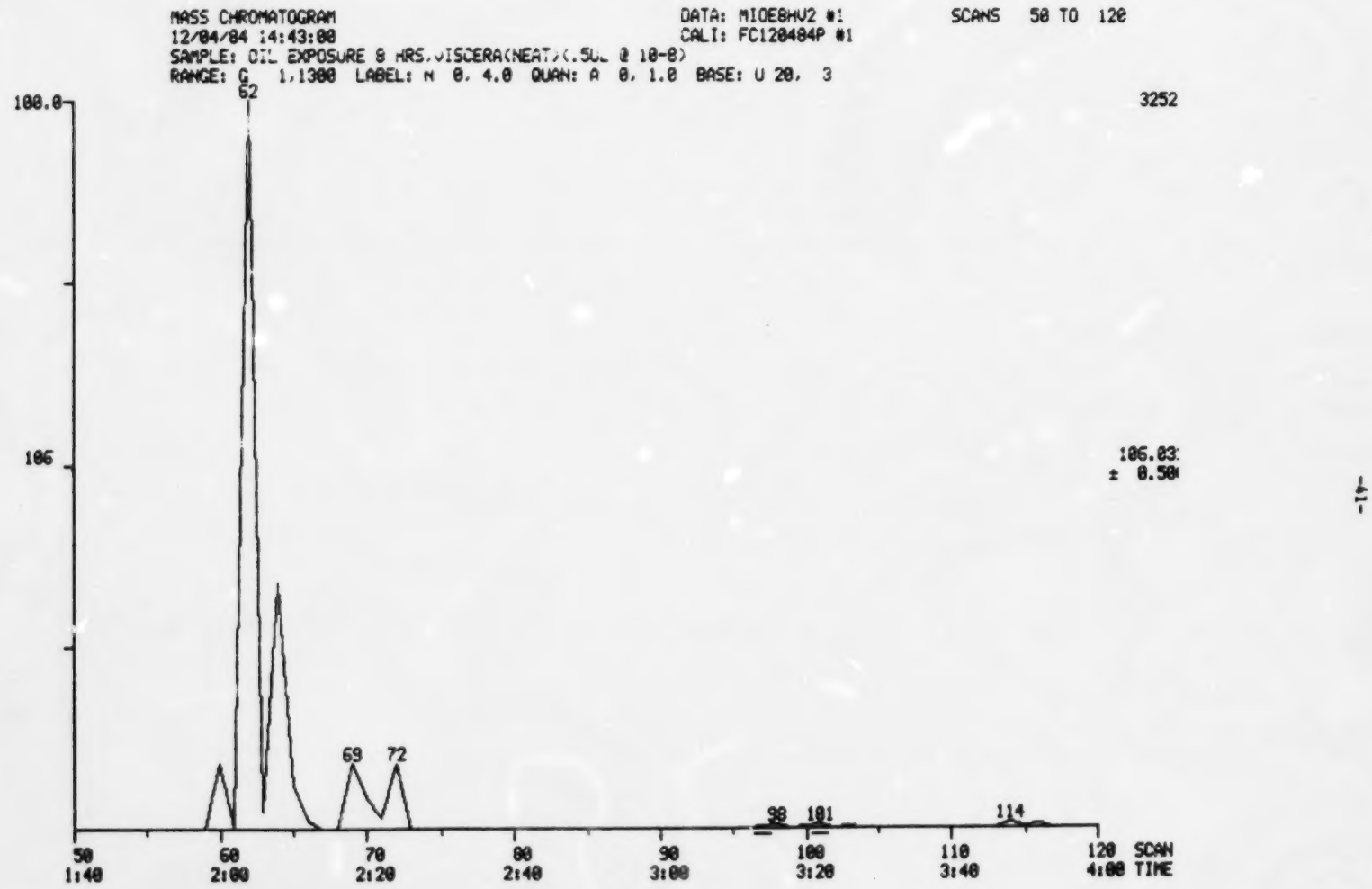

Fig. 37. Dimethylbenzenes indicator profile m/z=106, juvenile Atlantic salmon, viscera, 8-h exposure to gas condensate.
X-axis: scan numbers and times
Y-axes: intensity of ions normalized to the most intense peak (see absolute intensities on the right).
m/z 106 dimethylbenzenes; m/z 120 trimethylbenzenes; m/z 128 naphthalene; m/z 134 tetramethylbenzenes;
m/z 142 1- and 2-methylnaphthalene; m/z 156 dimethylnaphthalenes.

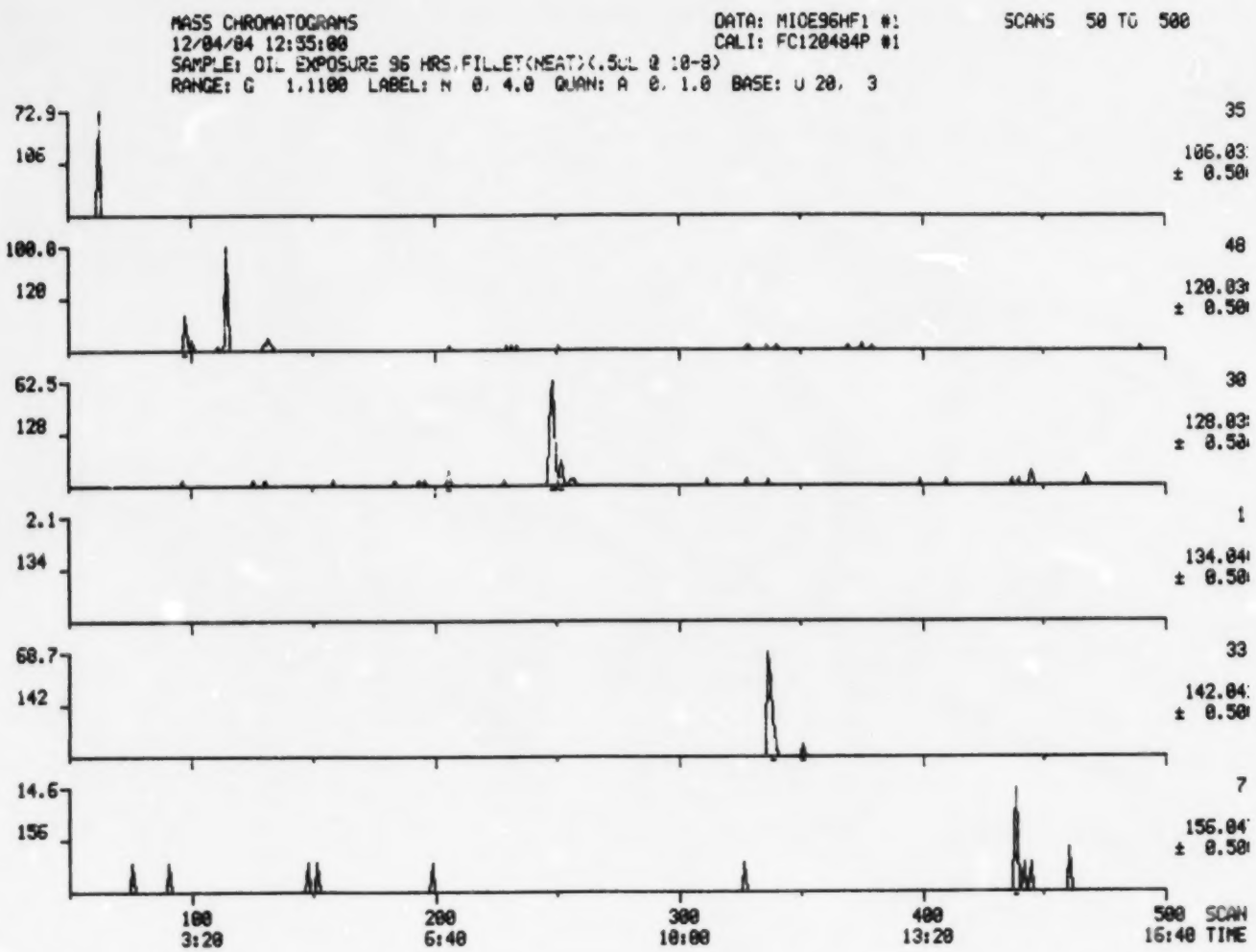

Fig. 38. Indicator hydrocarbon profile, juvenile Atlantic salmon, fillet, 88-h after exposure to gas condensate.
X-axis: scan numbers and times
Y-axes: intensity of ions normalized to the most intense peak (see absolute intensities on the right).
m/z 106 dimethylbenzenes; m/z 120 trimethylbenzenes; m/z 128 naphthalene; m/z 134 tetramethylbenzenes;
m/z 142 1- and 2-methylnaphthalene; m/z 156 dimethylnaphthalenes.

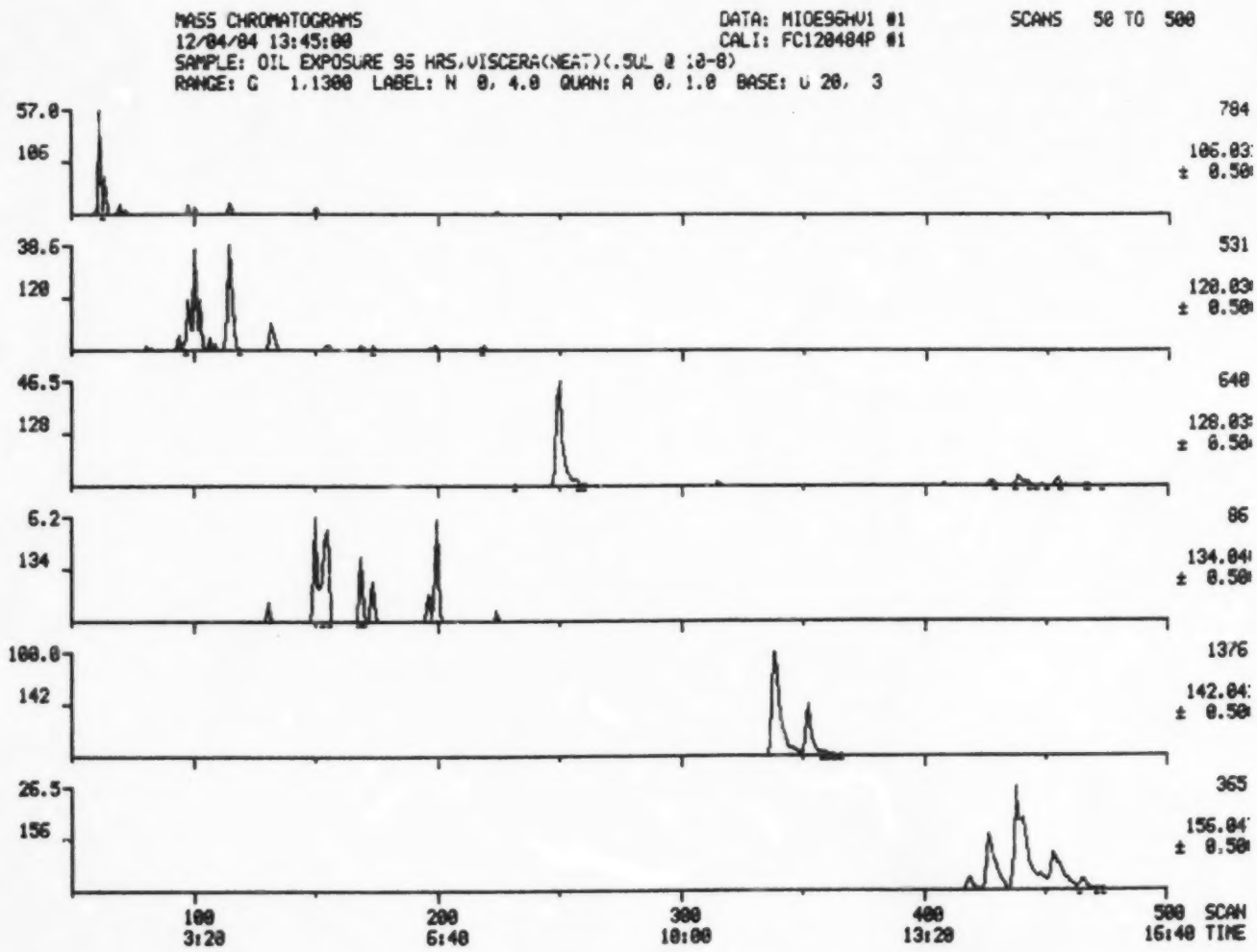

Fig. 39. Indicator hydrocarbon profile, juvenile Atlantic salmon, viscera, 88-h after exposure to gas condensate.
X-axis: scan numbers and times
Y-axes: intensity of ions normalized to the most intense peak (see absolute intensities on the right).
m/z 106 dimethylbenzenes; m/z 120 trimethylbenzenes; m/z 128 naphthalene; m/z 134 tetramethylbenzenes;
m/z 142 1- and 2-methylnaphthalene; m/z 156 dimethylnaphthalenes.